

**“GENOTYPE X ENVIRONMENT INTERACTION
ANALYSIS AND VARIATION STUDIES IN WINGED
BEAN [*Psophocarpus tetragonolobus* (L.) DC.]”**

Thesis
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NAGALAND UNIVERSITY

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of

Doctor of Philosophy

in

Genetics and Plant Breeding

by

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DECLARATION

I, Jarman Gadi hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

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This is to certify that the thesis entitled “**Genotype x environment interaction analysis and variation studies in winged bean [*Psophocarpus tetragonolobus* (L.) DC.]**” submitted to Nagaland University in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in the discipline of Genetics and Plant Breeding, is the record of research work carried out by Mr. Jarman Gadi, Admn. No. Ph– 279/19 Regn. No. Ph. D/GPB/00340 (2019-2020) under my personal supervision and guidance.

The result of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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GENETICS AND PLANT BREEDING**

This is to certify that the thesis entitled “**Genotype x environment interaction analysis and variation studies in winged bean [*Psophocarpus tetragonolobus* (L.) DC.]**” submitted by Jarman Gadi, Admn. No. Ph– 279/19 Regn. No. Ph. D/GPB/00340 (2019-2020), to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Genetics and Plant Breeding has been examined by the Advisory Board on and External Examiner

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LIST OF ABBREVIATIONS

Abbreviations for Units

%: Percent	°C: Degree Celsius
ppm: Parts per million	°E: East
cm: Centimetre	°N: North
m: Meter	µg: Microgram
m ² : Meter square	g: Gram
ha: Hectare	Kg: Kilogram
mm: Millimetre	M: Molar
hrs.: Hours	mM: mili Molar
nm: nanometre	ng: Nanogram

Abbreviations for Genetic Parameters

df: Degree of freedom	CD: Critical difference
µ: Population mean	GA: Genetic advance
ANOVA: Analysis of Variance	GAM: Genetic advance as per cent of mean
$\bar{X}$: Mean	CV: Coefficient of variation
SEm: Standard error of mean	PCV: Phenotypic coefficient of variation
σ^2_g : Genotypic variance	GCV: Genotypic coefficient of variation
σ^2_p : Phenotypic variance	ECV: Environmental coefficient of variation
σ^2_e : Environmental variance	b: Regression coefficient
E: Environment	S ² di: Deviation from regression
r: Correlation coefficient	PIC: Polymorphism information content
r ² : Coefficient of determination	NJ: Neighbour-Joining
F ₁ : Filial generation	h ² bs: Heritability for broad sense
NC: National Check	UPGMA: Unweighted pair group method using arithmetic average
PC: Principal Component	AEA: Average-Environment Axis
IPCA: Interaction of Principal Component Analysis	GEI: Genotype x Environment Interaction

Abbreviations for Observations

DFF: Days to 50% flowering	SI: 100 seed weight
DM: Days to maturity	PYPP: Pod yield per plant
DPI: Days to pod initiation	DFPF: Days to 50% flowering
PH: Plant height	NPPP: Number of pods/plant
TL: Tuber length	SYYP: Seed yield per plant
TDI: Tuber Diameter	TWE: Tuber weight
NSPP: Number of seed per pod	DPW: Dry pod weight
PL: Pod length	PW: Pod Width

Abbreviations for Other Parameters

Temp.: Temperature	V: Volume
PCA: Principal component analysis	Viz.: Namely
<i>et al.</i> : and co-workers	v/s: versus
RBD: Randomized block design	MSL: Mean Sea level
RH: Relative humidity	SAS: School of Agricultural Sciences
and: And	E: Environment
@: At the rate of	GEI: Genotype $\times$ Environment Interaction
Max.: Maximum	DAE: Days after emergence
Min.: Minimum	DAS: Days after sowing
NS: Non-Significant	DMSO: Di-methyl sulphoxide

ABSTRACT

Winged beans have significant potential to improve food and nutrition security, but this potential is often hindered by limited genetic improvement efforts. A major challenge to establishing effective breeding programs is the insufficient data on the genetic diversity within winged bean germplasm. The study evaluated forty winged bean accessions for genetic diversity and stability using sixteen quantitative traits, analyzing G x E interactions and their effects on winged bean variation across different environments, and identifying an ideal environment. A different models like additive main effect and multiplicative interactions (AMMI 1, AMM2), and genotype plus genotype–environment (GGE) interactions were used to understand their suitability in the precise estimation of variance and their interaction along with genotypic diversity. In this study 40 genotypes of winged bean were evaluated at the research farm SAS, Nagaland University Medziphema, India. Collected from different locations of Nagaland and IIVR-Varanasi and sown in three different dates. The experiment was conducted during summer 2022-23 and 2023-24, respectively.

The environment provide were Timely, Late and Very Late conditions which was conducted using (RCBD). Analysis of variance (ANOVA) indicates statistically significant differences at (5%) Among the 40 genotypes for all the yield variables evaluated. in which VRWB-17 exhibited Superior performances for the yield and field attributing characters. The present study revealed a substantial genetic variation for yield and yield attributing traits along with high heritability for all the traits. A strong Correlation were observed between seed yield per plant and several traits like number of seed per pod, number of pods per plant, seed index, Pod yield per plant and plant height. The correlation was constant at both the genotypic and phenotypic levels. Pod yield per plant exhibits the strongest influence on Number of pods per plant followed by pod yield per plant and Seed index.

D² analysis confirmed high genetic diversity among the genotypes. They were grouped into five clusters in the pooled environment combination. Among them Cluster-I shows the largest with 33 genotypes which was followed by cluster II with (3 genotypes). Pooled environment showed that the Cluster-II and Cluster-V having the highest inter-cluster distance. In the Mahalanobis' D² Statistics revealed the percent contribution to the genetic diversity in differential analysis where the tuber weight (37.05%) dominated in the pooled environment analysis. The findings highlight the diversity of the genotypes across the environments which offers the crucial information for the future breeding programme.

According to Eberhart and Russel model (1966), the analysis of variance recorded the presence of significant Genotype x Environment interactions for all the characters studied which indicated the presence of variability among the genotypes and variation in the environments. All the 40 genotypes reflected variability in six individual environments and pooled environments. Stability analysis indicates the significant interaction of G X E in which Local - Mongsenyimti, Local-Pangti-1, Local Pangti-2, NUWB-1, NUWB-2, VRWB-36, VRWB-54 and VRWB-116 were found most adaptable and stable for all the environments which results shows unity ($b_i=1$) among the given conditions. In the Environmental indices, Environment-1 (timely condition) is identified to be the most ideal test environment. AMMI2 analysis found stable environments and genotypes proximity to the origin with seed yield per plant for the genotype Local Peren (G4), Local suchonoma (G2), VRWB-54 (G24), VRWB-20 (G7), VRWB-26 (G11) and VRWB-27 (G12) and environments E1, E2 and E6 were identified as the most responsive/interactive. On the other hand, genotypes VRWB-50(G23), Local Pangti-2(G20), Local Dimapur-1(G18) and Local Dimapur-2 (G21) which were located close to the origin and hence were considered nonsensitive to environmental interaction. The first principal component (PC1) and the second principal component (PC2) independently

explained the variation Environments with the longest vectors from the origin separated the genotypes the most, but those with the shortest vectors from the origin segregated the genotypes rather well. For seed yield per plant, condition E1, E5 and E6 had the longest vectors from the origin, whereas E2, E3 and E4 had the shortest vectors. Using the Average Environment Coordination (AEC) approach, for seed yield per plant, VRWB-20 (G7), VRWB-17 (G6), G11 VRWB-26, (G31) VRWB-88 and G1 Local Wokha-2 were the genotypes with the most increased PC1 value. As per mean vs. stability approach VRWB-20 (G7), VRWB-17 (G6) and VRWB-26 (G11) indicates higher yield across environment. The maximum protein percent was recorded in VRWB-23 (28.17%) followed by VRWB-75 (27.81%) and Local pangti-2 (27.08%) genotypes green pods and for seeds it was maximum in VRWB-23 (32.56%) followed Local pangti-2 and Local pangti-1 (48.75%) and NUWB-4 (46.80%) genotypes. The maximum oil percent was recorded in VRWB-116 (14.80%) followed by VRWB-85 (14.30%), Local Mongsenyimti (14.30%), Local suchonoma (13.60%) and Local wokha-1(13.34%) genotypes. For total chlorophyll content VRWB-27, VRWB-24, VRWB-100, VRWB-104 and VRWB-116 genotypes showed significant contribution among all genotypes.

Key words – *Winged Bean, Variability, Correlation, Path analysis, Heritability, D² analysis Genetic Diversity, Stability, AMMI, G X E*

CHAPTER I

INTRODUCTION

INTRODUCTION

As the world faces increasing challenges related to food security, climate change, and the sustainability of agriculture, the winged bean, *Psophocarpus tetragonolobus*, stands out as a promising crop that could help meet these demands especially in the developing countries where high-protein sources like meat and grains are scarce and expensive. The 1970s marked the beginning of serious scientific interest in the winged bean, spurred by the need to address food shortages and malnutrition in tropical regions. Early studies confirmed that "winged bean seeds contain high levels of protein, similar to soybeans, with up to 37% protein content" (Nwokolo and Smartt., 1978). This discovery opened new possibilities for the crop as a sustainable protein source. Studies by Harder and Smartt (1980) highlighted the plant's ability to fix atmospheric nitrogen, which helps improve soil fertility and reduces the need for synthetic fertilizers. These early studies established the winged bean as a promising legume for low-input, sustainable farming systems. With its high protein content and adaptability to a wide range of environmental conditions, the winged bean could be a key component in diversifying agricultural systems and improving resilience against climate variability.

Psophocarpus tetragonolobus also known as winged bean, asparagus pea, Goa bean, Manila bean, Mauritius bean, four-cornered bean and four-angled bean is mostly a neglected and underutilized legume predominantly grown on a small scale as a subsistence crop in hot and humid equatorial countries throughout the Indian subcontinent, Southeast Asia, the Western Pacific islands, and some parts of Africa (NAS, 1981; Klu, 2002; Khan, 1976; Harder, 1992; Harder and Smartt, 1992). The cultivation of the winged bean (*Psophocarpus tetragonolobus*) in India is relatively limited, despite the crop's potential to thrive in the country's tropical and subtropical regions. "The

winged bean has shown great potential for cultivation in India's tropical regions, particularly in terms of soil enrichment due to its nitrogen-fixing properties" (Rao *et al.*, 2019) especially in the southern states such as Kerala, Tamil Nadu, and parts of Karnataka. The high rainfall, warm temperatures, and humidity typical of states like Assam, Manipur, Meghalaya, and Nagaland in the northeastern part of India provide an ideal environment for the crop to thrive. Favorable agro-climatic conditions of "the northeastern region of India, with its tropical and sub-tropical climate, is well-suited for the cultivation of winged bean, which thrives in such environments" (Singh and Baruah, 2020).

Taxonomically classified as a member of the Phaseoloid Sub-family of Leguminosae (Fabaceae), the winged bean is a dicotyledonous, hardy, self-pollinating crop and thrives in hot, humid tropical climates (Hymowitz and Boyd., 1977). The plants are herbaceous perennial but mainly grown as annual. It has a vining habit, tuberous roots, and longitudinally winged pods. Its leguminous crop is diploid ($2n=2x-18$), self-fertile, and has a wide range of uses (NAS, 1975). The leaves of winged bean are trifoliate, alternate, subtended by a stipule oval to ovate on the entire margin. The plant, which can reach a height of 5-7 m, produces blue, bluish-white, or purple blooms on pseudo-racemes that can appear alone or in groups of three (Lepcha *et al.*, 2017). The calyx tube is long, inflorescence is axillary, raceme and bearing many flowers. Maximum flower opening is between 10 AM to 12 noon. The plant has a cleistogamous floral system and is a structurally autogamous crop with self-pollination having been observed to take place before the large flowers open in the morning hours (Karikari., 1972; Erskine and Bala.,1976; Erskine., 1980) . Winged bean pollens are spheroidal, measuring 42.3-51.6 μ m on the polar axis and 43.4-49.9 μ m on the equatorial axis, and are extremely unique within the genus (Poole., 1979). It bears pods that grow upto a length of 11-30 cm and about 3cm in width that are four-cornered in structure, and with each one bearing a wing, hence the name

(National Research Council., 1981). Some varieties produce starchy underground tubers that are 2-4 cm in diameter and 8-12 cm long (NAS, 1975). In addition, winged bean is a generally non-selective nitrogen-fixing plant that can develop nodules in conjunction with broad-spectrum cowpea *Rhizobium* strains in tropical and cold climates, even in soils with no history of growing legumes (Elmes, 1976).

The importance of this crop lies in its exceptional nutritional value and the multi-purposefulness of the entire plant. The different parts of the winged bean act as a source of protein, calcium, and iron-rich vegetable, including immature pods (2.9-21.5% protein), ripe seeds (31.8% protein), tender shoots (2.8-5.6% protein), blossoms (2.92% protein). young leaves (3.24% protein), and tuberous roots (8-20% protein) (Neeliyara *et al.*, 2001), thus earning it the nickname ‘the soybean of the tropics’, ‘Godsent vegetable’ and ‘vegetable of twentieth century’ (Peter, 1998). The winged bean contains a higher quantity of thiamine, riboflavin, and niacin than soybeans and other beans (Ekpenyong and Borchers, 1980; Garcia, 1979). In winged bean seed oil, γ -tocopherol was revealed to be the dominant form, with a trace amount of α -, β - and δ -tocopherols (De Lumen and Fiad, 1982). One of its most notable characteristics is its nitrogen-fixing ability, which improves soil fertility by naturally adding nitrogen back into the soil. Research indicates that “winged bean cultivation is ideal for low-input farming systems, as it thrives in poor soils and helps maintain soil health” (Singh and Verma., 2020).

In 1975, the International Institute of Tropical Agriculture (IITA) began studying the winged bean’s potential as a protein source for tropical countries. Following on from the initial concerted research effort, winged bean research activities have expanded to include further characterisation of anti-nutritional factors in mature seeds (Umemoto *et al.*, 1992; Habu *et al.*, 1992, 1997; Mukhopadhyay, 2000) as well as factors affecting plant growth and

development (Schiavinato and Válio 1996a, b). And more recently, development of genetic resources like molecular markers for genetic diversity assessment (Mohanty *et al.*, 2013; Chen *et al.*, 2015; Wong *et al.*, 2017; Yang *et al.*, 2018) or clonal fidelity (Koshy *et al.*, 2013b).

Understanding the genetic diversity of existing landraces from various geographical regions is critical for their conservation and, subsequently, their utilization in breeding efforts. This information on genetic diversity is required by plant breeders for development of effective approaches, as well as provide information on heterotic combinations in crop improvement programs. The assessment of genetic diversity further entails the study of environmental alteration brought about in the crop and path coefficient analysis to determine the effect of a component trait on agro-morphometric properties of the plant. Environmental alteration greatly influences the yield, as it is a complex inherited character. Nature and magnitude of genetic variability among the genotypes are the main parameters in creating improvement in such traits. In addition to that information, character association and direct and indirect effects of component traits on agro-morphometric properties would help greatly in formulating a selection criterion which can be applied effectively in crop improvement programs. Path coefficient analysis breaks the genotypic coefficients into direct and indirect effects of the component characters on its yield based on which crop improvement can be done more successfully. Breeding and selection program often encompass several characters simultaneously (Hill *et al.*, 1998).

Peoples of tribal areas of the north eastern states of India use the winged bean in their diet in the form of young pods and seeds. The locally grown crops, first of all, lack scientific approach in its cultivation. Secondly, the local germplasm, vastly untapped, leaves much room for genetic improvement. For this highly nutritive underutilized (now a day's potential crop) vegetable to be a matter of choice of farmers / consumers its crop improvement must be carried

out. Genetic studies conducted by Kaul and Das, (2004), revealed that “there is considerable genetic diversity within winged bean populations, allowing for breeding programs to develop higher-yielding and more resilient varieties”.

For any crop improvement programme, availability and assessment is a prerequisite in this crop. Hence, an attempt was made to estimate variability, stability and association analysis in locally procured accessions and selected genotypes of winged bean recruited from deemed institution IIVR, Varanasi. While most genotypes do not perform consistently across all environments, superior genotypes should maintain high yields under diverse conditions (Carvalho *et al.*, 1983). Stability analysis enables breeders to assess genotype adaptability and select those best suited for widespread cultivation. Given the strong environmental impact on yield, multi-environment trials conducted over multiple years are essential for identifying superior genotypes.

To analyze GEI and assess genotype stability, the AMMI (Additive Main Effects and Multiplicative Interaction) and GGE (Genotype + Genotype $\times$ Environment Interaction) biplot models are widely used in plant breeding programs (Yan *et al.*, 2000; Ebdon and Gauch, 2002; Samonte *et al.*, 2005). These models help differentiate genetic performance from environmental influence, ensuring more accurate selection of high-yielding genotypes. Researchers have successfully applied these techniques to validate stable, high-yielding genotypes across various crops (Bhartiya *et al.*, 2017; Mortazavian *et al.*, 2014; Rad *et al.*, 2013; Yan *et al.*, 2007; Tiwari and Rastogi., 2020; Greveniotis *et al.*, 2022; Tiwari *et al.*, 2022).

The AMMI model integrates principal component analysis (PCA) with ANOVA to separate additive main effects from multiplicative interaction effects, making it a powerful tool for multilocation trials (Alizadeh *et al.*, 2017). The AMMI Stability Value (ASV), proposed by Purchase *et al.*, (2000), ranks

genotypes based on their stability. Similarly, GGE biplot analysis evaluates both genotypic performance and genotype-environment interactions, facilitating the selection of genotypes with superior adaptability (Singh *et al.*, 2019; Philanim *et al.*, 2022; Srivastava *et al.*, 2021).

Understanding genotype performance across different environments is essential for breeding programs aimed at improving winged bean productivity. By utilizing stability analysis methods such as AMMI and GGE biplots, researchers can effectively identify genotypes that combine high yield potential with broad adaptability, contributing to sustainable agricultural practices.

The goal of the current study was to evaluate **“Genotype x environment interaction analysis and variation studies in winged bean [*Psophocarpus tetragonolobus* (L.) DC.]”** collected from all over the India and especially the parts of northeast and determine the genetic diversity among them. This research will aid the selection of advanced breeding lines for release to growers and elucidate the genetic structure of winged bean accessions grown in India for breeding and conservation purposes.

From the above conclusion present study was focused on following objectives:

- i. To characterize the qualitative and quantitative traits in the various genotypes of winged bean.
- ii. To assess the genetic variability present among winged bean genotypes.
- iii. To determine the degree and direction of association among different yield contributing traits in winged bean.
- iv. To find out the direct and indirect contributions of independent variables on dependent traits in winged bean.
- v. To measure the extent of genetic diversity and stability among winged bean genotypes.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The literature relevant for the present study entitled “**Genotype X environment interaction analysis and variation studies in winged bean [*Psophocarpus tetragonolobus* (L.) DC.]**” has been reviewed in this chapter as under following:

2.1. Genetic variability, heritability and genetic advance

2.2. Correlation analysis

2.3. Path analysis

2.4. Genetic divergence

2.5. Stability analysis

2.6. AMMI and GGE Biplot analysis

2.7. Protein content analysis of winged bean

2.8. Oil content evaluation of winged bean

2.9. Chlorophyll content of winged bean

2.10. Morphological Characterisation in winged bean

2.1. Genetic variability, heritability and genetic advance:

Genetic variability is a fundamental requirement in any crop breeding programme. The efficiency of selecting largely depends upon the magnitude of variability present in the breeding population. The variability results due to differences in the genetic constitution present in the population or due to the influence in the environment. The variability is important for the resistance if the abiotic and biotic factors as well as for wide adaptability. Hence the knowledge of variability present in gene pool of a crop species is essential to start a judicious breeding programme.

A population's enduring differences among individuals, which may result from an individual's genetic makeup are referred to as variability. Plant populations with more diversity have a higher chance of developing new

genetic traits. Understanding of this notion is aided by Wilhelm Johannsen's pure-line concept from 1903. Maximum variety produces desirable kinds and requires crop improvement through selection, as Vavilov (1951) demonstrated. Genotypic variation is caused by additive, dominance, and epistatic effects, according to Fisher's (1918) classification of phenotypic variance into genotypic and environmental variance. For plant breeders to begin breeding programmes in any crop, the level of genetic variety in a population is essential. Fisher was the first to show how to use the right statistical techniques to distinguish between genotypic and phenotypic effects resulting from genotypic and environmental variables. Phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) can be calculated by estimating phenotypic, genotypic, and environmental variances. Here are a few reviews that discuss the genetic factors influencing the variability of certain characters.

The greatest degree of variation in germplasm or any breeding material demonstrates the greatest opportunity for transmitting the development via selection, but the coherence of selection mostly depends on the extent of character. In populations with great genetic diversity, traits are more likely to be inherited. The direct selection factors like heritability in the broad sense (Burton and Devane, 1952) and genetic advance as a percentage of mean (Johnson *et al.* 1955) are crucial techniques for evaluating the characteristics' transmissibility and the influence of the environment on each one. Heritability, when used broadly, refers to the genetic variation in a population relative to the total observable variance, and genetic advance refers to the genetic advancement of a chosen plant over the base population. Here are a few reviews that discuss the genetic factors influencing the broad sense heritability and genetic advance of certain characters.

Nandan *et al.*, (2009) studied the Twenty-one diverse winged bean genotypes which were evaluated for phenotypic and genotypic variability,

heritability and genetic advance in nine quantitative traits. Considerable amount of genetic variability was exhibited by Days to 50% flowering, pod length, dry pod weight, 100 seed weight and seed yield per plant, which indicates additive gene effects to provide a rapid genetic improvement. The genetic advance and heritability estimates suggested that the characters days to 50% flowering, days to maturity, number of pods per plant, dry pod weight, 100 seed weight and pod yield per plant were under additive gene effects.

Nandan *et al.*, (2010) evaluated 21 different genotypes for genotypic and phenotypic variation, heritability and genetic advance in nine quantitative traits of winged beans and found massive differences between each of the genotypes for characters like days to 50% flowering, pod length, 100 seed weight and yield of seed per plant. The study also showed strong heritability for yield of seed per plant estimates with moderate genetic advance as percentage of mean.

Sunanda *et al.*, (2012) studied the genetic diversity, heritability and correlation of ten accessions of winged bean. The PCV revealed higher than that of GCV for plant height, number of branches per plant, number of pods per plant, 100 seed weight and seed yield per plant.

Patel *et al.*, (2014) recorded in the black gram that grain yield per plant showed positive and was significantly correlated with days to 50 per cent flowering, clusters per plant, days to maturity, number of branches per plant, number of number of pods per plant, number of seeds/pod, pod length and 100-seed weight.

Prasanth *et al.*, (2014) studied that the traits in the winged bean viz., primary branches per plant days to first flowering, days to 50 per cent flowering, days to first harvest and pod weight exhibited high heritability coupled with high to moderate genetic advance as percent mean indicates the presence of

flexible additive gene effects, which may be improved through simple plant selection methods.

Ramya *et al.*, (2014) recorded a high estimation of PCV and GCV in black gram for its primary branches per plant, number of clusters per plant, number of pods per plant and single plant yield.

Rai and Dharmatti, (2014) studied the analysis of variance for different quantitative characters for 31 genotypes of cluster bean are presented and the results indicated that there is highly significant variation among the genotypes for almost all the characters under study, viz., plant height (cm), number of branches, days to 50% flowering, pods per plant, clusters per plant, pods per cluster, pod length (cm), number of seeds per pod, yield per plant (g), yield per hectare (t) and pod breadth (cm).

Prasanth *et al.*, (2015) studied 21 genotypes of winged bean for various seed characters with respect to their genetic parameters. They concluded that the character for number of pods per plant had high GCV and PCV. High heritability along with moderate to high genetic advance as percentage of mean had been observed in number of seeds per pod and number of pods per plant.

Gowsalya *et al.*, (2016) studied 11 quantitative characters in eight genotypes of black gram during *Rabi* to assess the genetic variability and character association. Selection based on number of pods per plant, number of seeds per pod and 100-seed weight helps in improving the seed yield of black gram.

Singh *et al.*, (2016) conducted a study on winged bean genotypes, including both indigenous and exotic accessions, with Maysoor local as the check variety. Their research focused on genetic variability and character associations. The study identified significant differences among genotypes, with green seed yield, number of green pods per plant, and total leaf area being the

most variable traits. Traits like green pod yield/plant and number of green pods /plant exhibited high heritability and genetic advance, emphasizing their importance in selection programs for further improvement. Phenotypic correlation analysis high lightened that the number of green pods per plant had the strongest positive correlation with green pod yield per plant. Path coefficient analysis showed that the number of green pods per plant was the primary character contributing directly and indirectly, through other component characters, to the maximum extent towards green pod yield per plant.

Singh *et al.*, (2016) studied the evaluated fifteen-winged bean genotypes for genetic variability. Significant differences was found among genotypes for all traits, with green seed yield per plant, number of green pods per plant, and total leaf area being highly variable. Traits like green pod yield per plant and number of green pods per plant showed high heritability and genetic advance, indicating their significance for selection. Phenotypic correlations revealed strong associations, especially with number of green pods per plant. The study suggests ample variability for improving green pod yield, with a focus on direct selection based on the number of green pods per plant.

Nashra *et al.*, (2018) evaluated 39 genotypes of black gram along with two checks to evaluate genetic variability, correlation of yield highly in black gram. Genotypes were tested in RBD and 13 characters were studied. Biological yield, seed yield per plant, harvest index, exhibited high GCV, PCV and genetic parameters revealed broad sense heritability and genetic advance as per cent mean values were high for seed yield per plant indicating that selection would be desirable for improvement of these traits.

Dodake *et al.*, (2018) studied the examined variability in 30 genotypes of winged bean across twelve traits. Maximum Genetic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were observed for number of pods per plot, indicating significant variability. High heritability and

genetic advance as a percentage of mean were found in traits like number of pods per plot, seed yield per plant, 100 seed weight, suggesting additive genetic control. Characters such as pod length and pod width showed lower GCV and heritability. Traits like number of pods/plot and 100 seed weight displayed both high heritability and genetic advance, suggesting potential improvement through simple selection.

Kant and Nandan, (2018) conducted a study on the performance and variability evaluation for seed characters and flower colour among 27 genotypes of winged bean. According to their report, based on different characters, the genotype Ambika WB-13-6 exhibited the high mean performance for seed yield per plant (31.96 g), mature pod length (17.44 cm), mature pod width (2.11 cm) and Number of seeds/pod (13.67) with 70 days for 50% flowering as well as average leaf area index at 50% flowering (1.35). They observed creamy white color, black colour and brown colour types of seed coat as well as white and violet types flowers and indicating variation among 27 genotypes of winged bean.

Yadav, (2018) evaluated 10 genotypes of winged bean for genetic variability. High heritability along with high genetic advance as percentage of mean were observed for traits like number of green pods per plant, green seed yield per plant, green pod yield per plant and 100 green seed weight.

Sarode and Dodake, (2019) studied variability in 40 genotypes for twelve characters in winged bean. They reported that the number of pods per plot exhibited maximum GCV and PCV among the traits followed by seed yield per plot, the number of pods per plant and seed yield per plant suggested the presence of more variability. The least GCV were recorded for days to first pod maturity followed by days to 50% flowering. All the characters showed high heritability except pod length and pod width. Characters like number of pods per plot, seed yield per plant, 100 seed weight, seed yield per plot, number of

Pods per plant and number of seeds per pod having high heritability estimates associated with high genetic advance as per cent of mean suggesting additive genetic control. They concluded that these characters could be improved through simple selection.

Sushmitharaj *et al.*, (2018) recorded high a GCV and PCV for the traits in 30 genotypes of cluster bean viz., number of clusters per plant, number of pods per plant, 100-seed weight and single plant yield.

Desai *et al.*, (2020) evaluated the extent of genetic variability, heritability, genetic advance, correlation coefficient, path coefficient and stability analysis in twenty green gram genotypes for twelve agro-morphological traits. Significant differences were found among twenty genotypes for twelve characters in the analysis of variance. Maximum GCV and PCV estimates were found for seed yield per plant, number of pods per plant. Seed yield was positively and significantly associated with the yield component at the genotypic and phenotypic level.

Adegboyega *et al.*, (2021) Investigates the variation in growth parameters, seed yield, nodulation, and nitrogen fixation in underutilized winged bean germplasms. Underlining the potential of winged beans for improved yield and economic traits, the research highlights high genotypic and phenotypic variances in the evaluated traits. The study emphasizes the significance of genetic variability in winged beans, suggesting careful exploitation for enhanced grain yield and other economically important traits. The findings contribute to the understanding of underutilized legumes, addressing the need for research investment, breeding programs, and awareness to boost food security and conserve plant genetic materials.

Dutta *et al.*, (2021) studied the Evaluation of 40 soybean genotypes over two years, which revealed significant variability in yield and traits. RVSM2011-

35 showed the highest seed yield and promising oil content, making it suitable for Assam. NRC 148 excelled in oil content and mean seed yield. Traits like seed yield/plant, number of seeds and pod, and oil content exhibited high genetic variability. Key traits with a high heritability and genetic advance included seed yield/plant, number of seeds, number of pods, oil content, and plant characteristics, indicating their potential for improvement through simple selection.

Sriwichai *et al.*, (2021) studied the 10-winged bean accessions at Khon Kaen, Thailand. According to their observation, the principal effects of the year (Y) and genotype (G) were significant for total pod weight and the number of pods. In addition, the YG interactions were principal effects upon the total pod weights and tuber weights. Their result indicated that superior genotype and appropriate environmental conditions are key elements in successful winged bean production for both pod and tuber yields.

Thakur *et al.*, (2022) carried an investigation on soybean with 25 genotypes, traits showed significant differences. Minimal environmental influence was indicated by small gaps between phenotypic and genotypic variations. Traits like pods per plant and seeds/plant demonstrated a high heritability, genetic advance, and genotypic coefficients-highlighting their potential for soybean improvement through phenotypic selection and promising genetic gains. This underscores the significance of genetic variation in enhancing soybean yield.

2.2. Correlation analysis

The complete knowledge or interrelationship of plant character like seed yield with the character of paramount importance in the breeding for making improvement in complex quantitative characters like seed yield for which direct selection is not much effective. Hence association analysis should be undertaken

to determine direction of selection and number of characters to be in improving seed yield.

Mohamadali and Madalageri, (2012) observed that seed yield/plant showed positive and significant correlation with the seed weight per pod, number of seeds/pods, dry pod weight and number of pods/plant.

Ahmed and Kamaluddin, (2013) conducted experiment on 57 germplasm lines of rajmash beans for yield and yield contributing traits by studying correlation and path analysis. Significant variations were observed for plant height number of pods 100 seeds weight and seed yield. High heritability coupled with high genetic advance were observed for plant height, 100 seeds weight and days to 50% flowering. Seed yield was found to be positively correlated with days to 50% flowering plant height, pod length, number of pods per plant and number of seeds per pod

Kushwaha *et al.*, (2014) studied correlation, path analysis and protein content of twenty-six genotypes of winged bean. Yield per plant and number of pods were explicative variables included in the study that presented the best combinations of pod coefficient and correlation, both positive and of and both were superior to that of the variable number of seeds per pod.

Prasanth *et al.*, (2014) study of correlation was taken up to gather information on the inter-relationship among all eleven characters of winged bean which shows highly significant positive estimates of both genotypic and phenotypic correlation coefficient by number of green pods per plant and days to green pod stage for green pod yield per plant are the indicative of potential applicability of these traits in indirect selection programmes for improving green pod yield per plant.

Panigrahi *et al.*, (2015) studied genetic divergence, variability and character association for yield components in black gram on 14 genotypes. Days

to 50 per cent flowering, number of pods per plant and 100 seed weight showed positive direct effect on yield.

Singh *et al.*, (2016) estimated among the 15 genotypes of black gram in which correlations were higher in magnitude than the phenotypic correlation indicating strong inherent relationship among the characters except few which could be due to modifying effects in the environment studied.

Singh, (2016) reported maximum positive phenotypic correlation with the green pod yield per plant with number of green pods per plant in winged bean.

Ramandeep *et al.*, (2017) studied correlation and path analysis in French bean for yield and yield attributing traits. They concluded that maximum direct contribution was made by pod weight followed by number of pods, total sugar content and days to first picking. High positive indirect effect was found in the case of pod weight via pod length, pod width and days to first picking.

Sushmitharaj *et al.*, (2018) studied the correlation coefficient of black gram and recorded that seed yield per plant showed positive association with the traits viz., plant height, number of pods per plant and number of clusters per plant. Hence, simultaneous selection for the above traits would be more rewarding to bring improvement in black gram.

Yadav, (2018) reported maximum positive significant phenotypic association with green pod yield per plant was showed by green seeds per pod followed by green seed yield/plant, pod length and days to pod initiation.

Gowd *et al.*, (2020) reported that very high positive direct effect on fresh pod yield per plant was exerted by number of cluster per pod at genotypic level while pod length, number of pod per plant, and exerted a positive and high direct effect on fresh pod yield per plant at both genotypic and phenotypic level. High

negative direct effect was exerted by days to first flowering and days to 50% flowering.

Ghasolia *et al.*, (2023) the experiment was conducted on cluster bean identifying the correlation among characters and direct and indirect effect on seed yield per plant of 10 genotypes. Seed yield per plant showed significant and positively correlated with traits like number of cluster per plant, number of pods per plant, pod length and biological yield per plant/plant. Days to 50% flowering has negative and significant correlation with the seed yield per plant. The number of clusters per plant exhibited maximum direct effect on seed yield per plant followed by days to maturity, number of pods per plant and biological yield. Negative indirect effect on pod length, pod width and 100 seed weight.

2.3 Path coefficient analysis

Path coefficient method by Dewey and Lu, (1959) has been widely used to estimate the magnitude and its effects of various yields and contributing characters. Correlation coefficients together with the path coefficients provides more reliable information which can be effectively utilized in crop improvement programme.

Ahmed and Kamaluddin, (2013) conducted correlation and path analysis in 57 germplasm lines of rajmash beans for yield and yield contributing traits. Significant variations were observed for plant height number of pods 100 seeds weight and seed yield. High heritability along with high genetic advance were observed for plant height, 100 seeds weight and days to 50% flowering. Seed yield was found to be positively correlated with days to 50% flowering plant height, pod length, number of pods per plant and number of seeds per pod. Path coefficient analysis revealed was 50% flowering. number of pods per plant, pod length and 100 seed weight showed positive direct effect on seed yield. Negative indirect effect was observed in days to pod initiation.

Kushwaha *et al.*, (2014) studied correlation, path analysis and protein content in twenty-six genotypes of winged bean. The explicative variable weight of 100 seeds correlated negatively with that of grain yield although its path coefficient was found to be positive.

Mathivathana *et al.*, (2015) investigated 65 genotypes urd bean were studied for path effects for eleven traits and revealed that dry matter production was the principal component responsible for increasing its seed yield in black-gram and it showed a high positive direct effect on the seed yield.

Jyothsna *et al.*, (2016) conducted studied on 12 genotypes black gram (*Vigna mungo* (L.) Hepper) to estimate the genetic parameters like variability, heritability and genetic advance, character association and path analysis for six quantitative characters viz., plant height, number of branches/plant, number of pods/plant, number of seeds/pod, length of the pod and seed yield.

Singh *et al.*, (2016) Studied the maximum positive phenotypic correlation in the winged bean [*Psophocarpus tetragonolobus* (L.) DC.] with the green pod yield per plant was exhibited by number of green pods per plant followed by total leaf area and days to green pod stage Path coefficient analysis indicated that number of green pods per plant was the main character that contributed to the maximum extent directly and via other component characters towards the green pod yield per plant also It can be inferred that there is ample variability for further improvement for green pod yield per plant and number of green pods per plant should be applied as direct selection criterion.

2.4. Genetic divergence

Genetic diversity refers to the genetic variation present between genetic stocks in relation to a particular character or a range of characters. They are the elements of inherent genetic variability found in the germplasm. To obtain a desired parents for breeding program, knowledge of the direction and degree of

genetic divergence is beneficial. D statistics was introduced by Mahalanobis in 1928. D^2 were identified as a means of quantitative estimates of genetic diversity between populations by Mahalanobis, (1936).

The importance of genetic divergence for improving yield potential, per se through hybridization has been emphasized by several authors and reviewed by Frey (1971). Although, it has long been appreciated by breeders, the basic difficulty has always been one of recognizing and reliable estimation of such diversity without making actual crosses (Bhatt, 1970). Mahalanobis (1928, 1936) developed model for classifying genetically divergent parents which has been widely used in psychometry and Anthropology purpose has been exploited by many scientists in various crops including winged bean. Murty and Arunachalam (1966) hypothesized that Mahalanobis D^2 statistic could be useful multivariate tool for effective discrimination among parents on the basis of genetic diversity. Canonical (Vector) analysis which is also known as Principal Component Analysis has some advantages over Tocher method as it measures divergence, in terms of spatial distance. Non-hierarchical Euclidean cluster analysis had an additional advantage of identifying sub-clusters of the major groups at different levels and each small group can be critically analyzed.

Fatiha *et al.*, (2012) observed *Psophocarpus* (Leguminosae; Papilionideae) is a genus of eight African Tropical legumes. Species with one cultivated Asian species (*P. tetragonolobus*). The growing interest using wild family members as a source of adaptive characteristics for breeding led us able to understand the phylogenetic relationships within the genus.

Chavez *et al.*, (2017) studied 25 accessions of winged bean for various quantitative characters with respect to their genetic diversity. The observed low to high diversity in terms of quantitative traits.

Agrawal and Choudhary, (2017) conducted a detailed morphological characterization of winged bean germplasm, documenting variations in pod length, seed size, and leaf morphology across different accessions. Their study highlighted the diversity of morphological traits and their potential utility in breeding for improved cultivars.

Nantawanit *et al.*, (2019) evaluated morphological diversity in winged bean landraces from Thailand, focusing on traits such as pod color, flowering pattern, and growth habit. Their findings contributed to the conservation and utilization of locally adapted germplasm for sustainable agriculture.

Yulianah *et al.*, (2020) studied 21 selected Indonesian winged bean lines based on observation of morphological characters to assess genetic diversity. This was the first step in determining an appropriate breeding program for the development of improved vegetable cultivars. Several of these characters are useful as genetic markers, and cluster analysis of the 21 lines on the basis of qualitative characters enabled two distinct groupings to be identified. Quantitative variation across line means was also high for several of the quantitative variables (a coefficient of variation > 25% for pod length, number of pods per plant, and total pod weight per plant). Principal component analysis applied to the eight variables accounted for 86% of the total variation in just three components with eigenvalues > 1. On Component 1, the characters number of days to first open flower, pod length and pod weight were closely aligned with total weight of pods per plant. Number of pods per plant was not closely aligned with weight of pods per plant.

Chandra *et al.*, (2021) evaluated the morphological diversity of winged bean accessions from India, highlighting variations in leaf size, flower color, and pod morphology. Their research emphasized the importance of morphological diversity in maintaining genetic resources and improving agronomic traits.

Subedi *et al.*, (2021) reviewed breeding strategies in winged bean focusing on improving nutritional traits and stress tolerance through genetic enhancement. They emphasized the importance of utilizing diverse germplasm for sustainable agricultural practices.

Akhtar *et al.*, (2022) discussed conservation strategies for winged bean genetic resources, emphasizing the need for preserving diverse germplasm to enhance agricultural resilience and food security.

Das *et al.*, (2022) conducted a detailed morpho-agronomic characterization of winged bean landraces in Bangladesh, identifying diverse traits related to pod morphology, seed size, and flowering pattern. Their findings provided insights into the adaptation and potential utility of local germplasm.

Bhadmus *et al.*, (2023) conducted a genetic diversity analysis which suggested the availability of ample genetic variation in the winged bean germplasm collection at GRC-IITA, Ibadan, Nigeria. The agro-morphological analysis clearly reflected the existence of genetic variation. The positive and significant associations recorded among agro-morphological traits indicated the possibility of simultaneous trait improvement.

2.5. Stability analysis

The different genotypes varied in growth response to different environments and their relative ranking usually differ (Eberhart and Russel, 1966) and ultimately decides the selection of genotypes for a particular or different sowing dates for stabilizing higher yields (Finalay and Wilkinson, 1963; Eberhart and Russel, 1966 and Perkins and Jinks, 1968). Generally, the time of planting varies depending on the climatic condition of the region and the variety to be grown. Different varieties of winged bean are sensitive to change in environmental conditions where the crop is being grown. Therefore, it is necessitated to study genotype×environment interaction to identify stable

varieties in different environments (Sarma and Roy, 1993). A population, which can adjust its genotype or phenotype state in response to environmental fluctuation in such a way that it gives high and stable economic response, can be termed as “well buffered”. Graffius, (1956) emphasized, that the studies of the yield component can lead to simplification in genetic explanation of yield stability and hence, are valuable to breeders in predicting and determining the effects of environment. A dynamic approach for the interpretation of varietal adaptation to varying environments was developed Finlay and Wilkinson, (1963). According to their technique, when regression coefficient is 1.0, it indicates average stability, when it is associated with high mean; genotypes have general adaptability when associated with low mean, genotypes are poorly adapted to all environments.

2.5.1 Genetic x environment interaction

Genotypes when evaluated over a range of environments often change their rank in different environment. Thus, a specific genotype does not exhibit the same phenotypic performance under all environments and conversely different genotypes also responds differently to a specific environment, this variation arises from the lack of correspondence between the genetic and non-genetic effects commonly known as genotype x environment (G x E) interaction. Changes in rankings make it difficult for the plant breeder to decide which genotype should be selected. Progress from selection is also reduced due to effect of a large G x E interaction, as shown statistically by Comstock and Moll, (1963).

Comstock and Moll, (1963) categorized the environment as micro and macro environment while Bradshaw, (1964) divided the environmental variation into two factors *i.e.* predictable (soil type, planting date and agronomic practices) and unpredictable (seasonal fluctuation in weather and other factors). Genotype and environment interaction (GEI) should be investigated so that the

breeder can decide to restructure the programme to minimize the interaction effect or exploit it to produce varieties with specific adaptation to particular environment.

Eisemann *et al.*, (1990) GEI of an individual is determined by both genotype and environment; these two effects are not always additive which indicates that GEI are present. GEI results from the changes in the magnitude of difference between genotypes in different environment or changes in the relative ranking of the genotypes.

Allard and Bradshaw, (1964) pointed out that genotype x environment interaction is extremely complex, with 10 genotypes in 10 different environments. It forms 10145 types of interaction which would be large than the total number of plants that can be accommodate on the entire globe in case of maize. This interaction is a universal phenomenon whether the varieties are pure lines, single crosses or any other material. Different attempts have been made to solve the problems created by G x E interactions. Sprague and Federer, (1951), Comstock and Robinson, (1952b), Hanson *et al.*, (1956) and Comstock and Moll, (1963) developed the analysis of variance approach to estimate G x E interactions. These estimates provide information on the existence and magnitude of G x E interaction but give no measurement of the response of individual genotypes with the environment. Genotype x environment interaction are reported frequently for most quantitative traits in many cultivated crops.

Nath *et al.*, (2013) evaluated thirty Mungbean genotypes developed through mutation breeding from three parents—B1, B105, and SML32—across seven environments in West Bengal to assess genotype × environment interaction and yield performance. The analysis revealed a wide variation in seed yield and its components, Significant differences among genotypes, environments, and their interactions highlighted the importance of stability analysis in crop improvement programs. The analysis indicated that linear

components of variance were generally larger than non-linear components, suggesting predictability in the traits studied. Stability analysis following the Eberhart and Russell model, along with sustainability index estimates, identified stable genotypes, with stability for yield components often aligning with stability for seed yield per plant. Four mutant genotypes—CUM1, CUM4, CUM10, and CUM13—exhibited average stability and consistently high mean performance for seed yield per plant and its components, underscoring the role of genotype $\times$ environment interaction in selecting stable and high-yielding Mungbam varieties for sustainable agricultural practices.

Bharatiya *et al.*, (2017) experiment was carried out to study Genotype $\times$ Environment (G $\times$ E) interaction for seed yield in 36 soybean genotypes including check PS1092 over 3 diverse environments represented by different altitudes in Uttarakhand. Grain yield performances of soybean genotypes were evaluated during *Kharif* 2013 season using a randomized complete block design.

Monndo *et al.*, (2019) Studied yield stability for identifying new common bean cultivars with either specific or broad adaptation in target environments in this study assess genotype by environment (G $\times$ E) effects on agronomic performance of 78 lines selected Promising genotypes combining high seed yield potential and high stability across environments were identified. The environment contributed the most to the variability among lines.

Mulema *et al.*, (2019) Assessed yield stability of Ugandan winged bean landraces using multi-environment trials and the Eberhart and Russell model. The study highlighted genotypic differences in response to environmental variation, with some landraces showing stable performance across varying soil and climatic conditions.

Raiger *et al.*, (2019) carried out comparative study on stability parameters and proposed Genotypic selection index for selecting stable genotypes in winged bean (*Psophocarpus tetragonolobus*) according to Eberhart and Russel model with sustainability index model. The pooled analysis of variance indicated that environment and G X E interaction were significant for all characters. The differential effects of environment on genotypes were significant for all characters. It was concluded that the genotypes 'EC038955', NBRI-Sel were the most suitable variety for all the environments for seed yield and pod yield.

Tiwari *et al.*, (2020) Studied yield stability and adaptability of 05-winged bean [*Psophocarpus tetragonolobus* (L.) DC.] genotypes in which results revealed that winged bean yield performance was significantly influenced by G×E interaction followed by genotypic (G) and environment (E) effects, respectively. GGE biplot facilitated identification of genotypes possessing stable yields as well showing stable winged bean genotypes over environment

Yuliana *et al.*, (2020) estimated the genetic diversity among 21 selected Indonesian winged bean lines based on observation of morphological characters. Twelve qualitative characters and eight quantitative variables were assessed for each of the 21 lines. Categorical differences among lines were observed in characters such as leaflet, pod and seed shape, pod surface texture, and anthocyanin pigmentation of stem, flowers and pods. Several of these characters are useful as genetic markers, and cluster analysis of the 21 lines on the basis of qualitative characters enabled two distinct groupings to be identified. Quantitative variation across line means was also high for several of the quantitative variables (a coefficient of variation > 25% for pod length, number of pods per plant, and total pod weight per plant).

2.6. AMMI model and GGE Biplot

Suryani *et al.*, (2022). investigated the variability in total phenolic content and antioxidant activity of *Curcuma zanthorrhiza* and *C. aeruginosa*, two medicinal plants from the Zingiberaceae family, across three locations. Total phenolic content was measured using the Folin-Ciocalteu reagent, and antioxidant activity was assessed using the DPPH method. The total phenolic content ranged from 2.403 to 7.539 mg GAE/g DW, with the highest concentration in the Cursina 3 variety of *C. zanthorrhiza* from Cianjur. Antioxidant activity ranged from 2.443 to 14.960 $\mu\text{mol TE/g DW}$, with the highest activity in the Cursina 2 variety of *C. zanthorrhiza* from Bogor. Stable genotypes for phenolic antioxidant production were identified as G1, G6, G13, and G16. *C. zanthorrhiza* cultivars generally had higher total phenolic content and antioxidant activity compared to all *C. aeruginosa* genotypes across all locations. *C. zanthorrhiza* cultivars are recommended for mass plantation in suitable areas in West Java to optimize their potential for phenolic content and antioxidant activity.

Roy and Singh, (2009) used GGE biplot analysis to evaluate winged bean genotypes across multiple growing seasons in India. GGE biplots focus on genotype and genotype-by-environment interactions, making them useful for identifying both stable and high-performing genotypes. Their study included GGE biplot identified several "ideal" genotypes with both high yield and stability. Certain genotypes were found to be specifically adapted to environments with high rainfall, while others performed better in drier conditions, indicating that both generalists and specialists exist among winged bean genotypes. The study also highlighted the importance of multi-season trials, as certain genotypes performed inconsistently across years due to variations in climatic factors like temperature and humidity.

Zobel *et al.*, (2014) experimented with soybean (*Glycine max*), consisting of 10 cultivars grown at 5 sites for 4 years and describing 3-4

replications. It was shown that the AMMI model has been used successfully to diagnose the Genotype by Environment interaction (GxE) patterns in a number of situations and for a number of characteristics from daylength responses to yield to root numbers. The AMMI statistical model discussed in the study is most appropriately termed a hybrid model. It makes use of standard ANOVA procedures to separate the additive variance from the multiplicative variance (Genotype by Environment interaction - GxE) and then uses a multiplicative procedure - Principal Components Analysis (PCA) - to extract the pattern from the GxE portion of the ANOVA analysis. The resulting statistical model is a hybrid of the two models and results in a least squares analysis which, with further graphical representation of the numerical results (Biplot analysis), often allows a straight-forward interpretation of the underlying causes of GxE.

Nantawanit *et al.*, (2019) conducted AMMI analysis to evaluate stability of winged bean landraces in Thailand based on pod yield and quality traits. The study identified genotypes with stable performance across diverse ecological niches, supporting local cultivation practices.

Jifar *et al.*, (2019) studied 35 varieties which showed significant variations in grain yield due to genotype, environment, and their interaction. Genotype G6 had the highest yield, while G29 had the lowest. The environments and genotypes were grouped into four mega-environments and seven genotypic groups. Environments E5, E6, E7, and E8 were the most discriminating, while E1 and E4 were the most representative. Genotypes G6, G25, G34, and G16 were identified as high-yielding and stable. The study concluded that AMMI and GGE biplot models effectively grouped tef growing environments and genotypes.

Achenef and Alimou, (2020) evaluated twelve faba bean genotypes were evaluated using a randomized complete block design with four replications. The study aimed to identify stable faba bean genotypes for seed yield using the Additive Main Effects and Multiplicative Interaction (AMMI) model.

Significant differences ($P < 0.01$) were found among genotypes, environments, and genotype by environment interactions for the seed yield. The AMMI analysis showed that the environment accounted for 88.4% of the total variation, genotype by environment interaction accounted for 2.7%, and genotype alone accounted for 1.1%, highlighting the predominant influence of the environment on faba bean production. The decomposition of genotype by environment interactions into interaction principal component axes (IPCA) revealed that the first and second IPCAs explained 34.0% and 23.8% of the total $G \times E$ interaction, respectively, with these two IPCAs together explaining 57.8% of the total treatment variation. The AMMI-1 biplot indicated that genotypes and environments on the right side of the midpoint axis had higher yields, whereas those on the left side had lower yields. Genotypes G6, G8, and G2 were identified as relatively stable with small interaction effects, while G11, G3, G9, and G1 exhibited strong interaction effects. According to the AMMI Stability Value (ASV), genotypes G6, G2, G12 (Tumsa), and G8 were found to be widely adapted across environments with the lowest ASV scores. In contrast, genotypes G1 (Gora), G3, G5, and G11 were identified as unstable with the highest ASVs. The AMMI model also suggested specific genotypes for each environment: G11, G8, G4, and G3 for Assasa; G11, G3, G8, and G12 for Kulumsa; G12, G5, G1, and G8 for Bekoji; G12, G3, G8, and G5 for Adet; and G12, G1, G4, and G5 for Debark.

Makokha *et al.*, (2020) evaluated genotype stability of East African winged bean populations using SNP markers and AMMI analysis whereby the identified stable genotypes suitable for diverse agro-ecological conditions, enhancing regional cultivation strategies.

Chandra *et al.*, (2021) applied GGE biplot analysis to Indian winged bean accessions to identify stable genotypes for pod and seed yield. The findings highlighted genotypic diversity and stability under varying soil and climate conditions, aiding in cultivar selection and breeding.

Abou-Khater *et al.*, (2022) observed that the adaptability and stability of 37 faba bean (*Vicia faba* L.) accessions with varying levels of tolerance to metribuzin or imazethapyr were evaluated across 12 season-location-herbicide experiments. Significant genotype by environment (GE) interaction was observed for days to flowering (DFLR), plant height (PLHT), and grain yield (GY). Performance and stability of the accessions for PLHT and GY were assessed using four stability parameters: cultivar superiority, static stability, Wricke's eco-valence, and Finlay and Wilkinson's regression model. The different stability parameters ranked the genotypes differently, indicating the need to assess stability using multiple parameters. GGE biplot analysis identified metribuzin treatment at Marchouch 2014-2015 and the non-treated treatment at Terbol 2018-2019 as ideal environments for evaluating faba bean genotypes. The herbicide-tolerant accession IG12983 showed average PLHT, GY, and stability across environments. Other tolerant accessions, including IG13945, IG13906, IG106453, FB2648, and FB1216, were less stable but performed well in specific mega environments.

Greveniotis *et al.*, (2022) genotypes were evaluated for forage yield under both conventional and low-input cultivation systems using a strip-plot design. Significant positive correlations were found between forage yield and certain traits, suggesting that forage yield stability may be improved indirectly by enhancing these traits. The genotypes showed stable performance even in low-input farming systems. AMMI analysis, GGE biplot, and ANOVA revealed statistically significant differences between genotypes, environments, and farming systems. Specific cultivars were identified for different areas and farming systems to achieve highly stable performance. The two pea lines showed stable performance in Giannitsa and Florina areas, particularly under low-input conditions.

Soni *et al.*, (2022) conducted a study for proper understanding of genotypes and Genotype $\times$ Environment interactions (GEI) on yield and yield

component traits to identify best-performing stable genotypes across different environments where eleven genotypes of winged bean were characterized and evaluated in two locations for two years following a randomized block design with three replications. Characterization of genotypes showed varying leaf shape, leaflet size, pod surface, pod shape, seed colour, and seed shape. The AMMI based statistics was performed in R software 4.0.3 (R Core Team, 2020) using ‘metan’ package (Olivoto and Lucio, 2020). Results revealed that the winged bean yield and yield component traits were significantly influenced by GEI, genotypic and environmental effects.

Tiwari *et al.*, (2022) ascertained the gene $\times$ environment interaction (GEI), yield stability and adaptability of 05 winged bean (*Psophocarpus tetragonolobus* L.) genotypes in Chhattisgarh India by using AMMI and GGE biplot models which revealed that winged bean yield performance was significantly influenced by $G \times E$ interaction followed by genotypic (G) and environment (E) effects, respectively. GGE biplot facilitated identification of genotypes possessing stable yields as well as discriminating environments and specificity in adaptability of the genotypes to specific environments in a ‘which won where’ pattern.

Akinyose *et al.*, (2023) experimented to enhance yield potential of twenty-winged bean genotypes were evaluated under rainfed conditions using GGE biplot analysis as employed to identify high-yielding and stable genotypes from Asia and Nigeria. Seed yield varied from 805.61 kg/ha in Ibadan to 1,096.35 kg/ha in Kishi, averaging 988.42 kg/ha across all locations. The plants reached various growth stages at specific intervals after planting. GGE biplot analysis revealed that the principal component axes captured 71.5% of total variation, with genotype, environment, and their interaction significantly affecting seed yield. Environments IB20 and IF20 were most effective for genotype discrimination. Genotype Tpt-12 was identified as high-yielding and

stable, recommended for commercial farming in southwestern Nigeria, and promising for use in grain yield improvement programs.

Balbo *et al.*, (2024) studied the environment (E), and their interaction ($G \times E$) affect agronomic features and seed quality of chickpea (*Cicer arietinum* L.) and identified climatic variables impacting nutritional composition. Ten pre-commercial and commercial chickpea cultivars were evaluated across 15 environments in Argentina. Plant height ranged from 44.7 to 55.2 cm, 100-seed weight was between 27 and 38 g, and grain yield varied from 750 to 1500 kg ha⁻¹ for kabuli and desi chickpeas, respectively. Variance component analysis revealed significant contributions of G, E, and $G \times E$ interaction to nutritional quality. Environmental effects primarily influenced protein, carbohydrate, and mineral content, while oil content was dependent on genotype. Tocopherol content was affected by $G \times E$ interaction. High mean daily air temperature negatively impacted carbohydrate levels but increased protein and mineral content. Fatty acid profiles and gamma tocopherol levels were influenced by precipitation and evapotranspiration. Air humidity negatively correlated with protein content and iodine value. These findings help breeders expand chickpea genetic diversity and assist farmers in identifying climatic conditions that affect grain quality.

Paramanik *et al.*, (2024) aimed studied to assess the phenotypic stability of 27 French bean genotypes for yield and quality traits across four seasons using modern statistical tools such as AMMI (Additive Main Effects and Multiplicative Interaction), GGE (Genotype + Genotype $\times$ Environment), and cluster analysis. The analysis revealed that genotype (G), environment (E), and genotype $\times$ environment interaction ($G \times E$) accounted for 81.94%, 11.58%, and 6.48% of the total variation, respectively. The IPCA I (Interaction Principal Component Axes) contributed significantly to $G \times E$ variations for traits like days to 50% flowering, pod length, number of pods per plant, average pod weight, and pod yield. For qualitative traits such as protein content, total soluble

solids, and total phenol content, IPCA I explained substantial portions of the $G \times E$ interaction variations. The AMMI biplot identified genotypes IC632961, Arka Sukomal, IIHR-PV-29, and IIHR-PV-30 as having low AMMI stability values followed by high mean values for yield and quality traits across two mega-environments (late kharif and rabi). Cluster analysis then grouped the genotypes into five distinct categories based on Euclidean distance, showing diversity in response to changing environments. Pole-type genotypes like IC 632961 and Arka Sukomal, as well as bush-type genotypes such as IIHR-B-PV-29 and IIHR-B-PV-30, were identified as promising for future breeding programs focusing on relevant traits.

Pornsuriya *et al.*, (2024) undergoes studies and found out that significant effects of environment (E), genotype (G), and genotype $\times$ environment interaction (GE) on yield. Environmental main effects accounted for 77.68% of the total variation, while genotype and GE contributed 4.30% and 8.58%, respectively. The GGE biplot analysis revealed that the first two principal components (PC1 and PC2) captured the majority of the GEI variation. Among the genotypes, Bangpra2 (G2) was the most stable, being the closest to the ideal genotype on the GGE biplot. NO.25 (G8) and No.30 (G9) were the second and third most stable lines, respectively. The best environment for yield selection was Chonburi during the early rainy season with chemical fertilizers (E3), as it had the highest total environment GE score and was closest to the ideal environment on the GGE biplot.

2.7. Protein content analysis of winged bean

Li-wen *et al.*, (2010) analysed four cultivars of winged bean seeds for total protein content by the Kjeldahl method. The results showed total protein contents of 4 cultivars of winged bean seeds were approximately 38%.

Awoyale *et al.*, (2018) conducted a comparative study on the nutritional composition of several tropical legumes, including winged beans. They reported

protein content of approximately 32% in winged beans, which was higher than that of cowpeas and pigeon peas but slightly lower than soybeans.

Adegboyega *et al.*, (2019) determined proximate composition (fat, moisture content, crude protein, ash, and carbohydrate) and antinutrient (tannin and phytate) level of winged bean seeds and tubers using 50 accessions. Variations were observed in the crude protein content in a range of 40.30% to 28.43%.

Chakraborty *et al.*, (2019) studied the potential of winged bean protein in food fortification, particularly in cereal-based products. They found that incorporating winged bean protein improved the protein content and amino acid balance of the fortified products.

Moyib *et al.*, (2019) evaluated the nutritional composition of winged bean seeds from Nigeria and reported a protein content of approximately 33% by dry weight. The study emphasized the high lysine and tryptophan content, making winged bean protein a complete protein source.

Singh *et al.*, (2019) emphasized the high protein content of winged beans as one of its key nutritional attributes, with their findings showing an average protein content of 34% by dry weight. They highlighted the potential of winged bean protein in addressing protein malnutrition.

Yusuf and Adamu, (2019) explored the potential of winged bean protein isolates in fortifying traditional foods, providing a means to improve dietary protein intake in developing countries. Their research indicated that protein isolates from winged beans contained about 90% protein by dry weight.

Pratap *et al.*, (2020) analyzed the protein content of various winged bean accessions and found that the protein content ranged from 30% to 36% by dry

weight. The study also highlighted the presence of essential amino acids, particularly lysine, which constituted about 7%.

Wani *et al.*, (2020) explored the use of winged bean protein in developing high-protein food products such as protein bars and shakes. The study reported that winged bean protein enhanced the nutritional profile and sensory properties of the products.

Jain *et al.*, (2021) analyzed the proximate composition of winged bean seeds and found a protein content of 31-34% by dry weight. Their study noted the favorable amino acid profile of winged bean protein, making it a good alternative to other high-protein legumes.

Nguyen *et al.*, (2021) investigated the application of winged bean protein in aquaculture feed and found that it significantly improved the growth performance and health of fish, suggesting its potential as an alternative protein source in aquaculture.

Ushakumari *et al.*, (2021) studied the proximate composition and nutritional quality of winged bean seeds from India, finding that the protein content ranged from 31% to 35%. Their findings also indicated that the essential amino acid profile was comparable to that of soybeans

2.8. Oil content evaluation of winged bean

Li-wen *et al.*, (2010) analysed four cultivars of winged bean seeds for total lipid content and fatty acid composition by Soxhlet extraction coupled with gas chromatography and the results showed that the total lipid contents of 4 cultivars of winged bean seeds varied from 20% to 22% and 28 fatty acids were identified in each winged bean oil.

Ajayi *et al.*, (2017) emphasized the high oil content of winged beans as one of its key nutritional attributes, with their findings showing an average oil

content of 18% by dry weight. They highlighted the potential of winged bean oil in food and industrial applications.

Mahajan *et al.*, (2018) studied the properties of winged bean oil and its potential for food fortification. The study reported that the inclusion of winged bean oil in margarine and shortening formulations improved the nutritional profile of these products.

Okpara *et al.*, (2018) conducted a comparative study on oil content and fatty acid composition of several tropical legumes, including winged beans. They reported oil content of approximately 19% in winged beans, which was higher than that of cowpeas and pigeon peas, but slightly lower than soybeans.

Adegboyega *et al.*, (2019) determined proximate composition (fat, moisture content, crude protein, ash, and carbohydrate) and antinutrient (tannin and phytate) level of winged bean seeds and tubers using 50 accessions. Variations were observed in the fat content in a range of 13.87% to 19.01%.

Islam *et al.*, (2019) conducted a study on the oil content along with fatty acid composition of winged beans grown in Bangladesh. They reported an oil content of 16% by dry weight and highlighted that linoleic acid (36%) and oleic acid (27%) were the predominant fatty acids.

Udomkun *et al.*, (2019) demonstrated the use of winged bean oil in traditional cooking practices, noting its stability and favorable taste profile. The study suggested that winged bean oil could serve as an alternative to conventional vegetable oils.

Mitra and Pal, (2020) analyzed the proximate composition of winged bean seeds and found an oil content of 17-19% by dry weight. Their study noted the favorable fatty acid profile of winged bean oil, making it a good alternative to other vegetable oils.

Nguyen *et al.*, (2020) evaluated the lipid profile of winged bean seeds from different regions of Vietnam. They found that the oil content ranged from 17% to 19% by dry weight, with a high proportion of unsaturated fatty acids, particularly linoleic acid (35-38%) and oleic acid (25-28%).

Khan *et al.*, (2021) evaluated the nutritional and functional properties of winged bean oil and reported an oil content of approximately 18%. The study emphasized the oil's high unsaturated fatty acid content, with linoleic acid being the most abundant at 37%.

Lai *et al.*, (2021) explored the potential industrial applications of winged bean oil, including its use in cosmetics and pharmaceuticals due to its rich fatty acid composition and antioxidant properties.

2.9. Chlorophyll content of winged bean

Sinha, (2014) studied the biochemical parameters like Chlorophyll, carbohydrate and protein content of *Psophocarpus tetragonolobus* (Winged bean) which were considered as measures to test the suitability of Winged bean in various soil-OB dump compositions (P1 to P5).

Zhao *et al.*, (2018) conducted a comparative study of chlorophyll content in various leafy vegetables, including winged beans and spinach. They reported that the chlorophyll content in winged bean leaves (2.5 mg/g) was comparable to that in spinach (2.8 mg/g), indicating that winged beans are a good source of chlorophyll.

Chatterjee *et al.*, (2019) studied the antioxidant and detoxification properties of winged bean chlorophyll. They found that winged bean chlorophyll extract exhibited significant antioxidant activity and supported detoxification processes in the body, suggesting its potential use in health supplements.

Rao and Deshpande, (2019) emphasized the high chlorophyll content of winged beans as one of its key nutritional attributes. Their findings showed that winged bean leaves had a total chlorophyll content of 2.6 mg/g, which was higher than that of lettuce (2.1 mg/g).

Samyori *et al.*, (2019) examined the chlorophyll composition of winged bean leaves and pods, reporting higher concentrations of chlorophyll a compared to chlorophyll b in both parts. They found that chlorophyll a levels were notably higher in leaves (2.3 mg/g) than in pods (1.6 mg/g), reflecting the photosynthetic activity in leaves.

Hossain *et al.*, (2020) evaluated the chlorophyll content in the leaves of winged beans grown under different light conditions. They reported that leaves grown under full sunlight had higher concentrations of chlorophyll content (2.7 mg/g), both chlorophyll a and b compared to those grown under shaded conditions (1.9 mg/g). This study highlighted the impact of environmental factors on chlorophyll synthesis.

Naveen *et al.*, (2020) explored the use of winged bean chlorophyll extract in functional food products. They reported that incorporating winged bean chlorophyll into smoothies and juices not only enhanced the nutritional value but also improved the sensory attributes of the products.

Nguyen *et al.*, (2021) studied the chlorophyll content in winged bean leaves at different stages of maturity. They found that younger leaves had higher chlorophyll content (3.0 mg/g) compared to older leaves (2.2 mg/g), noting changes in chlorophyll a and b concentrations as leaves matured. The study emphasized the importance of harvesting time to maximize chlorophyll content.

Wang *et al.*, (2021) investigated the use of winged bean chlorophyll as a natural food colorant, emphasizing its safety and sustainability compared to synthetic dyes.

2.10. Morphological Characterisation in winged bean.

Yulianah *et al.*, (2020) studied 21 selected Indonesian winged bean lines based on observation of morphological characters to assess genetic diversity. Twelve qualitative characters and eight quantitative variables were assessed for each of the 21 lines. Categorical differences among lines were observed in characters such as leaflet, pod and seed shape, pod surface texture, anthocyanin pigmentation of stem, flowers and pods. This study has enabled broad differences between groups of lines to be categorized and has identified particular lines with characteristics that recommend them for inclusion as parents in inheritance studies designed to elucidate the contribution that individual characters make to overall productivity and nutrition of this useful vegetable species.

Ishtifaiyyah *et al.*, (2021) evaluated twenty genotypes of Winged bean (*Psophocarpus tetragonolobus*) for agro-morphological traits and harvest period of eighth-generation winged bean genotypes. Several qualitative and quantitative traits were evaluated from each genotype. The results showed that there were variations among winged bean genotypes which were based on qualitative traits as well as the color of stem, calyx, corolla, pod, and pod wings. Purple coloration in the calyx of P1 and H3U genotypes was known to correspond with the purple color in stem, corolla, pod, and pod wings.

Yadav, (2021) experimented on Characterization of 27-winged bean was by studying 9 qualitative and six quantitative traits. Categorical differences among 27 germplasm lines including two checks viz. C.G. Chaudhari Sem-2 and U.P. local were observed in traits such as stem colour, leaflet shape, leaflet size, corolla colour, pod colour, pod shape, pod surface texture, seed colour, seed shape, tuber size, days to pod initiation, number of pods/plants, pod length, 100 seed weight and seed yield/plant. Several of these traits may be useful as genetic markers and in hybridization programme.

Sriwichai *et al.*, (2022) studied the population structure of 60 domestic (Thai) and 64 imported Winged bean [*Psophocarpus tetragonolobus* (L.) DC.] accessions were assessed via their comparative morphological traits. The Thai and imported winged bean populations were comparable in days to flowering, pod length and seed size. Majority of the Thai and imported winged bean accessions showed the same qualitative traits, including leaf shape, flower color, pod color and pod shape. These suggested the winged bean growers' similar preferences and selection of winged beans in different geographical regions.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was entitled as “**Genotype X environment interaction analysis and variation studies in winged bean [*Psophocarpus tetragonolobus* (L.) DC.]**” was carried out during two consecutive *summer* seasons of 2022 and 2023.

3.1 Experimental materials

3.2 Location, climate and description of experimental plot

3.3 Layout of the experiment

3.4 List of genotypes

3.5 Observations recorded

3.6 Statistical analyses

3.7. Biochemical tests

3.1. Experimental materials:

The experiment material for the present investigation consisted 40 Germplasm collected/recruited from the different areas of north east and also recruited from the deemed institution IIVR Varanasi.

3.2. Soil condition of experimental plot:

The soil condition of the Experimental site was loamy sand (utisol) in texture with acidic in nature.

3.3 Location, climate and description of experimental plot:

The experiment was coordinated at Experimental farm of Department of Genetics and Plant Breeding, SAS, Medziphema, Nagaland. It is situated at 29°45'43" N latitudes and 93°53'04" E longitudes at an elevation of 304.80 m above mean sea level (MSL). The site of the experimental area falls under sub-tropical climate with high humidity, moderate temperature (Maximum 38° C during summer to minimum 6° C during winter) with medium to high rainfall (2000 to 2500 mm). The soil is acidic in nature with pH varying from 4.5 - 6.2 and the organic matter content of soil is low which varied from 1.2 - 2.9%. The

topography is fairly uniform and plot is well drained with assured irrigation facility to raise the healthy crop.

Table 3.1: Details of winged bean genotypes used in the study

S. No.	Genotypes	Place of collection	S. No.	Genotypes	Place of collection
1	VRWB-50	IIVR, Varanasi, UP	21	VRWB-104	IIVR, Varanasi, UP
2	VRWB-54	IIVR, Varanasi, UP	22	VRWB-112	IIVR, Varanasi, UP
3	VRWB-116	IIVR, Varanasi, UP	23	VRWB-115	IIVR, Varanasi, UP
4	VRWB-59	IIVR, Varanasi, UP	24	VRWB-88	IIVR, Varanasi, UP
5	VRWB-77	IIVR, Varanasi, UP	25	NUWB-3	SAS, Medziphema, Nagaland
6	VRWB-17	IIVR, Varanasi, UP	26	NUWB-2	SAS, Medziphema, Nagaland
7	VRWB-20	IIVR, Varanasi, UP	27	NUWB-4	SAS, Medziphema, Nagaland
8	VRWB-23	IIVR, Varanasi, UP	28	Local Mongsenyimti	Mongsenyimti, Nagaland
9	VRWB-24	IIVR, Varanasi, UP	29	Local Bagty	Bagty, Nagaland
10	VRWB-75	IIVR, Varanasi, UP	30	Local Dimapur-4	Dimapur, Nagaland
11	VRWB-26	IIVR, Varanasi, UP	31	Local Wokha - 1	Wokha, Nagaland
12	VRWB-27	IIVR, Varanasi, UP	32	Local Akuk	Akuk, Nagaland
13	NUWB-1	IIVR, Varanasi, UP	33	Local Dimapur-2	Dimapur, Nagaland
14	VRWB-32	IIVR, Varanasi, UP	34	Local Pangti-2	Pangti, Nagaland
15	VRWB-35	IIVR, Varanasi, UP	35	Local Dimpur-1	Dimapur, Nagaland
16	VRWB-36	IIVR, Varanasi, UP	36	Local Pangti – 1	Pangti, Nagaland
17	VRWB-85	IIVR, Varanasi, UP	37	Local Medziphema	Local Medziphema

18	VRWB-93	IIVR, Varanasi, UP	38	Local Peren	Peren, Nagaland
19	VRWB-45	IIVR, Varanasi, UP	39	Local Suchonoma	Suchonoma, Nagaland
20	VRWB- 100	IIVR, Varanasi, UP	40	Local Wokha-2	Wokha, Nagaland

The Standard week-wise weather data (temperature, relative humidity and rainfall) has been provided in **Table 3.2 and Fig.**

**Table 3.2 (a) Meteorological data during the period of crop investigation
(March – October 2022)**

Standard Week	Temp.		Relative humidity		Rainfall(mm)
	Max. (°c)	Min. (°c)	Max %	Min. %	
16-23 Mar.	30.7	18.4	90	63	18.2
24-31 Mar.	31.4	21.2	89	60	20.1
1-8 Apr.	33.2	20.2	90	62	22.1
9-16 Apr.	32.1	22.6	92	61	21.4
17-24 Apr.	34.1	24.1	87	63	21.3
25 Apr. - 02 May.	33.5	23.2	88	64	23.7
03- 10 May.	31.7	22.2	84	65	25.3
11-18 May.	33.3	23.3	93	65	22.5
19-27 May.	33.0	24.0	94	74	51.1
28 May. – 02 June.	30.3	23.3	95	74	46.7
03– 10 June.	31.2	23.4	95	75	34.8
11– 18 June.	33.3	24.9	93	68	9.9
19 -26 June.	34.2	24.7	91	66	77.1
27 Jun.– 04 Jul.	34.1	24.5	90	69	22.9
05– 12 Jul.	33.9	24.5	92	75	135.3
12-19 Jul.	31.8	23.2	96	70	135.3
20 Jul. – 27 Jul.	33.6	23.9	93	68	48.8
28 Jul. - 04 Aug.	33.3	23.9	96	71	114.7
05– 12 Aug.	33.6	24.2	91	72	27.5
13 18 Aug.	34.1	24.5	94	68	64.2
19-26 Aug.	32.7	24.3	93	68	9.0
27 Aug.- 03 Sept.	33.4	24.4	89	67	21.7
04- 11 Sept.	31.9	23.5	91	72	42.8
12 - 19 Sept.	33.5	24.0	91	65	15.3
20-27 Sept.	32.8	23.2	91	70	81.2
28 Sept.- 05 Oct.	31.9	23.5	95	74	31.0

06 -13 Oct.	31.8	22.7	91	71	2.9
14-21 Oct.	30.9	20.6	94	65	19.7
22-29 Oct.	28.1	19.9	95	71	41.0

Table 3.2 (b) Meteorological data during the period of crop investigation (March – October 2023)

Standard Week	Temperature		Relative humidity		Rainfall (mm)
	Max (°C)	Min(°C)	Max %	Min %	
16-23 Mar.	29.7	16.4	90	54	18.2
24-31Mar.	29.1	16.2	91	51	20.1
1-8 Apr.	34.7	16.2	82	37	0.0
9-16 Apr.	35.1	19.7	89	50	27.7
17-24 Apr.	31.7	18.3	86	59	20.2
25 Apr. - 02 May.	32.2	20.2	85	60	24.9
03- 10 May.	34.9	19.5	86	48	0.0
11-18 May.	30.4	20.8	92	63	24.5
19-27 May.	33.4	21.8	80	58	35.2
28 May. – 02 June.	35.8	22.8	85	49	2.5
03– 10 June.	36.9	24.1	84	61	77.1
11– 18 June.	30.2	23.6	93	80	107.2
19 -26 June.	30.2	23.6	92	77	63.2
27 Jun.– 04 Jul.	34.1	25.1	91	75	25.0
05– 12 Jul.	34.0	24.9	90	65	59.6
12-19 Jul.	33.0	25.1	92	73	4.4
20 Jul. – 27 Jul.	33.4	25.1	94	72	41.5
28 Jul. - 04 Aug.	34.0	25.0	93	70	123.6
05– 12 Aug.	34.2	25.1	92	74	112.3
13-18 Aug.	32.3	25.1	91	76	73.2
19-26 Aug.	33.0	25.3	92	74	41.9
27 Aug.- 03 Sept.	31.5	24.6	93	81	70.6
04- 11 Sept.	32.6	24.5	93	67	16.2
12 - 19 Sept.	35.3	25.1	92	68	21.3
20-27 Sept.	33.4	24.9	93	70	18.2
28 Sept.- 05 Oct.	32.3	24.3	94	75	48.4
06 -13 Oct.	33.5	24.1	92	70	70.9
14-21 Oct.	31.5	24.1	93	76	23.8
22-29 Oct.	31.0	22.7	92	67	1.2

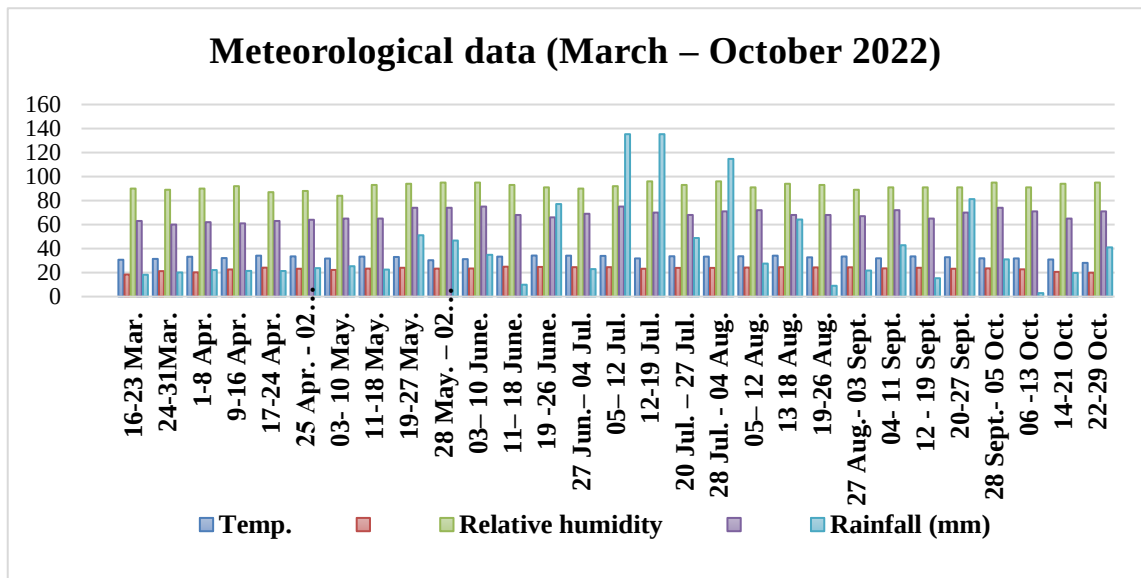


Figure 3.1(a) Meteorological data during the period of crop investigation (March – October 2022)

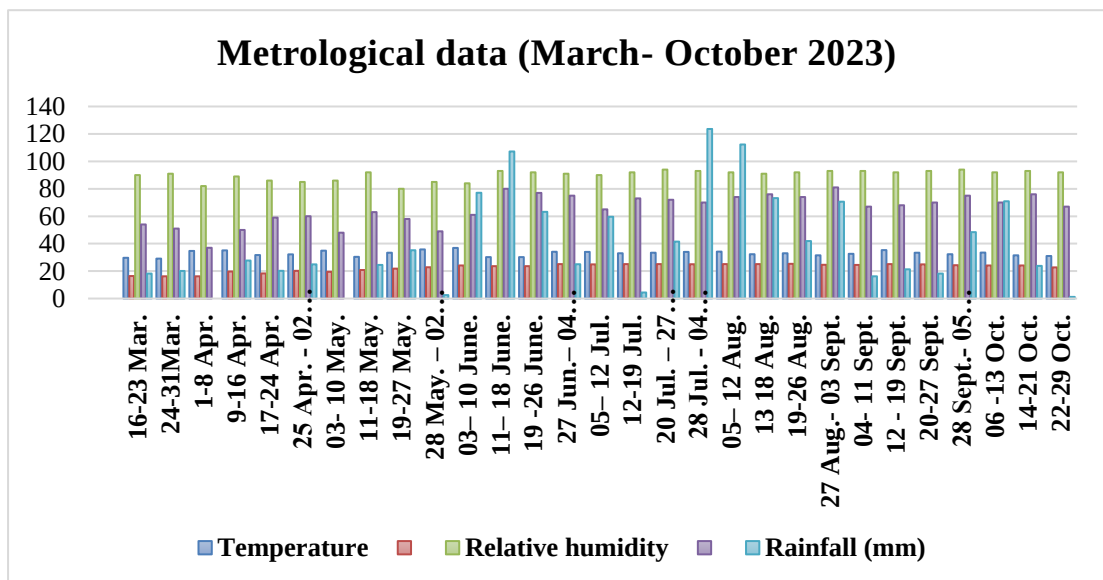


Figure 3.1(b) Meteorological data during the period of crop investigation (March – October 2023)

3.4. Layout of the experiment:

1. Design: RBD
2. Number of replications: 3
3. Number of genotypes: 40
4. Row to Row spacing: 0.5 m
5. Plant to Plant spacing: 0.5 m
6. Plot size: 3m x 2m
7. Distance between replication: 1m
8. Distance between treatments: 0.6 m
9. Total number of plots: 120
10. Method of sowing: Line sowing at the depth of 2.5- 3 cm.

3.4.1. Design of experiment

The experiment was assigned in Randomized Block Design with 3 replications under both divergence and stability study. The experimental material were consisted of 40 genotypes of [*Psophocarpus tetragonolobus* (L.) DC].

3.4.2. Date of sowing

The present investigation was conducted under early sown (E1, E4), timely sown (E2, E5) and late sown (E3, E6) conditions over two years at Experimental Farm of department of Genetics and Plant breeding, SASRD, Medziphema, Nagaland, during *Summer*, 2022-2023 as well as 2023-24. Thus, the following six environments were created by varying different date of sowing, at an interval of fifteen days over two years. The details of environment are given in **Table 3.3**.

Table 3.3. Details of different environment and notation

Environment	Sowing dates (with Ten days interval)
Env 1	<i>Summer</i> (2 nd fortnight)-16 th March, 2022-2023
Env 2	<i>Summer</i> (2 nd fortnight)-26 th March, 2022-2023
Env 3	<i>Summer</i> (1 st fortnight)- 5 th April, 2022-2023
Env 4	<i>Summer</i> (2 nd fortnight)- 16 th March, 2023 -2024
Env 5	<i>Summer</i> (2 nd fortnight)- 26 th March 2023 -2024

Env 6	Summer (1 st fortnight)- 5 th April, 2023 -2024

3.4.3. Methods

The experimental materials comprising of 40-winged bean Genotypes (procured from various parts of north-eastern states and IIVR, Varanasi) were sown and grow in Randomized Complete Block Design along with three replications during *kharif* season 2021 and 2022. Each entry was sown in single row of three meters length. In both the years of *summer* season (6 environments) was involved by sowing the genotypes in 3 different dates at 10 days interval respectively, observations were recorded on five randomly selected plants from each genotype in each replication. The spacing between row-to-row was 120 cm and plant to plant distance of 100 cm maintained by thinning after 15 days of sowing and also entries were given equal dose of fertilizers as per recommended.

Sometimes, the unilocal trials can also serve the purpose by providing different environments created by planting experimental material at different sowing dates on the same location (Luthra *et al.*, 1947 and Tehlan, 1973). Mather and Jinks, (1982), Mukai, (1988) and Wu and O'Malley, (1998) reported two types of environmental variations: (1) micro environmental variances, which cannot be easily identified or predicted (*e.g.* year-to year variation in rainfall, drought conditions, extent of the insects' damage) and (2) macro-environmental variances which can be identified or predicted (*e.g.* soil type, management practices, controlled temperatures).

3.4.4. Layout details

The details of the field layout are given below:

Design: : RBD (Randomized Block Design)

Replications: :3

Spacing :30 ×10 cm

Gross area :218 m²

Net area :194 m²

3.4.5. Field preparation

The experimental area was prepared as follows: the Experimental site was ploughed 2 times by tractor in the month of February and March, followed by two harrowing with the help of tractor drawn disc harrow. After thorough preparation of soil, plots were kept for solarization. Adequate nutrient supply for its optimum production and farm yard manure was applied in plots during field preparation.

3.4.6. Irrigation and Fertilizer application

It includes uniform fertilizer application, irrigation and agro-production practices followed to raise a healthy crop. The recommended fertilizer dose was applied once, as basal dose *i.e.* N: P₂O₅: K₂O: 30:30:20 Kg/ha one day before the date of sowing for the entire crop life.

3.4.7. Intercultural operations

Intercultural operations like thinning were done only once for the entire crop life at 15 DAE. 1st hand weeding at 21 DAE, 2nd hand weeding at 45 DAE followed by 3rd and 4th hand weeding at 60 and 75 DAE respectively in all the experiment (E1, E2, E3, E4, E5 and E6).

3.4.8. Pest management

Antigastra catalaunalis commonly known as blister beetle or capsule borer was controlled by spraying the insecticide carbaryl 50WP @ 20 ml per 10 liters of water at 45 and 65 DAE.

3.4.9. Disease Management

Powdery mildew infestation caused by *Erisiphe cichoreacearum* (**Reddy and Haripriya, 1990**) was controlled by spraying with fungicide *i.e.* wettable sulphate @ 0.25 gm/ litre of water at 40 and 60 DAS in all the experiment. Followed by appearance of viral or aphid (*Aphis Craccivora*) origin were

recorded on both the old and young leaves and pods thus affecting the productivity of the crop.

3.4.10. Seed treatment

The seeds were treated with Carbendazim @ 2g/ Kg seed to prevent the seed borne diseases.

3.4.11. Physiological maturity

Harvesting of the winged bean plants at right stage is very important to avoid the seed loss, since its pod has shattering potential. The entries were harvested at physiological maturity, when the dry matter, germination and vigour of seeds were at their maximum value. (Monalisa *et al.* 2018). Winged bean seed should be harvested when the plants reach fully matured dried stage (for optimal pod and oil yield).

3.5. Observation recorded

Observations were recorded for qualitative and quantitative characters. The average value of the five random selected plants for the chosen characters was calculated and operate for the statistical analysis. The techniques employed to record data on individual character are described here under.

3.5.1. Number of days to 50% flowering

Number of days to 50% flowering was recorded as the number of days taken from the date of sowing up to the date of flower initiation at least in 50% plants population.

3.5.2. Number of days to first flowering

Number of days to first flowering was recorded as the number of days taken from the date of sowing to the date of first flower initiation in a plot.

3.5.3. Number of days to pod initiation

Number of days to pod initiation was recorded as the number of days taken from the date of sowing to the date required for pod initiation in total population in a plot.

3.5.4. Number of days to maturity

Number of days to maturity was taken as the number of days taken from the date of sowing to the date on which pods of selected plants reached physiological maturity.

3.5.5. Total number of pods per plant

The number of pods originating from individual plant as a whole was counted as total number of pods per plant. The mean data will be obtained from arithmetic average of the number of pods per plant of five randomly chosen plants in a plot.

3.5.6. Plant height (cm)

Plant height was measured (cm) from the ground level up to the tip of the shoots on five randomly selected plants and then averaged.

3.5.7. Number of seeds per pod

Seeds from the selected pods of a chosen plant was counted and the mean seed number per pod was averaged.

3.5.8. 100 seed weight (g)

Weight of 100 selected seeds was determined using an electronic balance and expressed in gram.

3.5.10. Pod width and Pod length (cm)

Pod Width based on the mean of ten pods per plant.

3.5.11. Pod yield Per Plant(g)

Weight of 5 selected plants were taken and observed accordingly.

3.5.12. Dry Pod weight (g)

Pods from selected plant were collected and weighted, then averaged.

3.5.12. Days to green pod stage.

Number of days taken by the plant to bear the green pods from the date of sowing.

3.5.13. Pod Length (cm)

It is calculated as the mean of sum of pod length per plant.

3.5.14. Tuber length

Tuber length from the selected plants were taken and measured in cm.

3.5.15. Tuber diameter (cm)

Tuber was cleanly digged up and tuber diameter was measured at the widest part of the plant to its widest point using calipers.

3.5.16 Tuber weight (g)

Weight of the tubers from the selected plant were taken and then measured accordingly in gram.

The observed qualitative characters were in number, namely: stem color; leaflet shape; pod color; pod wing color; pod surface texture; pod shape; presence of pod specks; calyx color; corolla color; seed color; and seed shape (**Table 3.4**). These observations on qualitative characters was carried out using the ICAR, NBPGR (2015) descriptor list for winged bean.

Table 3.4. List of important qualitative characters to be observed based on the terminology of the modified ICAR, (NBPGR 2015) descriptor list.

Characters	Expression
Stem colour	Green (1), Greenish purple (2), Purple (3), Other (4)
Colour of wing pods	Green (1), Purple (2), Other (3)
Pod surface texture	Smooth (3), Medium (5), Rough (7)
Pod shape	Rectangular (1), Semi flat (2), Flat on side (3), Flat on suture (4)
Presence of pod specks	Absent (1), Present (2)
Leaflet shape	Ovate (1), Deltoid (2), Ovate lanceolate (3), Lanceolate (4), Long lanceolate (5)
Pod colour	Cream (1), Green (2), Pink (3), Purple (4), Other (5)
Calyx colour	Green (1), Greenish purple (2), Purple (3), Other (4)
Corolla colour	White (1), Blue (2), Purplish blue (3), Purple (4), Reddish purple (5)
Seed colour	Cream (1), Light Brown (2), Brown (3), Purple (4), Black (5), Brown-black (6), Purplish black (7), White (8).

3.6. Statistical and genetical analysis

Means of the various observations was subjected to the following statistical analyses for drawing appropriate conclusion for the present investigation.

3.6.1. Analysis of variance

3.6.2. Heritability and Genetic advance

3.6.3. Estimation of coefficient of variation

3.6.4. Estimation of Correlation and Path coefficient analysis

3.6.5. Estimation of genetic divergence using D^2 statistics.

3.6.6. Stability analysis

3.6.1. Analysis of variance

The analysis of variance for each character was carried out for the randomized complete block design RCBD Suggested by Fisher (1946). The replication wise mean values of 40 genotypes were subjected to RCBD analysis. The model used will be as follows:

$$Y_{ij} = \mu + b_i + t_j + e_{ij}$$

$$(i = 1, 2, 3, \dots, r)$$

$$(j = 1, 2, 3, \dots, t)$$

Where,

Y_{ij} = Observed response of i^{th} genotype in the j^{th} replication.

μ = General mean of population

b_i = Effect of i^{th} block

t_j = Effect of j^{th} treatment

e_{ij} = Random error of i^{th} block and j^{th} treatment

The skeleton ANOVA table for RBD with t treatments and r replications

Sources of variation	d-f	S.S	ms	F Value
Replication	r-1	R S S	R M S	R M S/ E M S

Treatment	t-1	Tr S S	Tr M S	Tr M S/E M S
Error	(r-1) (t-1)	E S S	E M S	
Total	Rt -1	T S S		

ANOVA (analysis of variance) for pooled data:

The total variation among genotype for different characters was tested for significance by 'F' test using analysis of variance technique. The degree of freedom, mean sum of squares and 'F' values were calculated as follows.

Sources of variation	D.F	S.S	M.S	F
Replication	(r-1)	S_r	MS_r	MS_r/MS_e
Season	(s-1)	S_s	MS_s	MS_s/MS_e
Season x Replication	(r-1)(s-1)	S_{sr}	MS_{sr}	MS_{sr}/MS_e
Overall sum	(rs-1)	S_{os}	MS_{os}	MS_{os}/MS_e
Genotype	(G-1)	S_g	MS_g	MS_g/MS_e
Pooled Error	(G-1)(rs-1)	S_e	MS_e	

Where,

- r = Number of replications
- g = Number of genotypes
- MS_r = Mean squares for replications
- MS_t = Mean squares for treatments
- MS_e = Mean squares for error

Critical difference (CD) calculated to test the significance of difference between any two treatments as follows:

$$C.D. = S.E.d \times t'$$

Where,

t = Table value of t at error degree of freedom

$S.\overline{Ed}$ = Standard error of difference between two treatment means

$$S.\overline{Ed} = \sqrt{\frac{2EMS}{r}}$$

$$CV \% = (\overline{SD}) / (\overline{X}) \times 100$$

$$SD = \sqrt{EMS}$$

Where, EMS = Error mean square (MSe)

r = number of replications.

SD = Standard deviation,

$\overline{X}$ = General mean of the character.

3.6.2. Heritability and genetic advance

Estimation of heritability

Heritability in broad sense (h^2_b) was estimated as the ratio of genotypic variance to the phenotypic variance (Allard, 1960). The heritability estimates was calculated as follows:

$$(h^2_b) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

where,

(h^2_b) = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

Expected genetic advance:

Expected genetic advance was estimated as suggested by Allard (1960).

$$GA = K \times \sigma_p \times h^2_b$$

where,

K = Selection differential expressed in standard unit

- σ_p = Phenotypic standard deviation calculated as square root of
. Phenotypic variance
 h^2_b = Heritability in broad sense
GA = Expected genetic advance

3.6.3. Estimation of coefficient of variation

The genotypic coefficient of variation (GCV), phenotypic (PCV) and environmental coefficient of variation (ECV) was estimated by (Burton *et al.* 1953).

$$\text{GCV percent} = \frac{\text{Genotypic standard deviation}(\sigma_g)}{\text{General mean}} \times 100$$

$$\text{PCV percent} = \frac{\text{Phenotypic standard deviation}(\sigma_p)}{\text{General mean}} \times 100$$

$$\text{ECV Percent} = \frac{\text{Environmental standard deviation}(\sigma_e)}{\text{General mean}} \times 100$$

3.6.4. Estimation of correlation and path coefficient

Correlation studies

The correlations between all the characters under study at genotypic, phenotypic and environmental levels was estimated according to the method given by Searle (1961) using the following formula:

1. Phenotypic correlation between characters X and Y

$$r_{xy}(p) = \frac{\text{Cov.XY}(p)}{\sqrt{\text{Var.X}(p) \times \text{Var.Y}(p)}}$$

2. Genotypic correlation between characters X and Y

$$r_{xy}(g) = \frac{\text{Cov.XY}(g)}{\sqrt{\text{Var.X}(g) \times \text{Var.Y}(g)}}$$

3. Environmental correlation between characters X and Y

$$r_{xy}(e) = \frac{\text{Cov.XY}(e)}{\sqrt{\text{Var.X}(e) \times \text{Var.Y}(e)}}$$

where,

Cov.XY(p), Cov.XY(g) and Cov.XY(e) denote phenotypic, genotypic and environmental covariance between characters X and Y, respectively. Var.X(p), Var.X(g) and Var.X(e) denote variance for character X, and Var.Y(p), Var.Y(g) and Var.Y(e) denotes phenotypic, genotypic and environmental variances for character Y, respectively.

Test statistic

$$t_c = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

Path coefficient analysis:

The phenotypic and genotypic correlation coefficients obtained from correlation study, can further be partitioned into direct and indirect effects using path coefficient analysis as suggested by Wright (1921) and then applied in plant breeding by Dewey and Lu (1959). If seed yield per plot is considered as dependent variable (y) as factors assumed to be influenced by the other characters called independent variables ($x_1 \dots x_i$) as causes. The path coefficient was estimated by solving following sets of simultaneous equations indicating the basic relationship between correlation and path coefficients.

$$\begin{aligned} R_{1y} &= P_{1y} + r_{12} P_{2y} + r_{13} P_{3y} + \dots + r_{1i} P_{iy} \\ R_{2y} &= P_{2y} + r_{21} P_{1y} + r_{23} P_{3y} + \dots + r_{2i} P_{iy} \\ R_{3y} &= P_{3y} + r_{31} P_{1y} + r_{32} P_{2y} + \dots + r_{3i} P_{iy} \\ R_{iy} &= P_{iy} + r_{i1} P_{1y} + r_{i2} P_{2y} + \dots + r_{i(i-1)} P_{i-1y} \end{aligned}$$

Where,

R_{1y} to R_{iy} = coefficient of correlation between independent variables (1...i) with dependent character y.

R_{12} , r_{11} to $r_{i(i-1)}$ = coefficients of correlation among all possible combinations of caused factors (independent variables), and

P_{1y} to P_{iy} = direct path effects of independent variables (1 to i) on the dependent variable y. The indirect effect of i^{th} independent variable through

j^{th} independent variable on dependent variable y was computed as $= P_{1y} \times r_{ij}$.

Path coefficient was estimated as follows:

$$C = B^{-1} A$$

The effect of residual factors (R) which measures the contribution of rest of the characters were not considered in the causal scheme. It was calculated as follows:

$$R^2 = 1 - \sum_{i=1} P_{iy}^2 - 2 \sum_{i,j=1} P_{iy} P_{jy} r_{ij}$$

Where, R = Residual factor.

3.6.5. Estimation of genetic divergence using D^2 statistic

Mahalanobis's D^2 statistic (Rao, 1952) will be used for estimation of genetic divergence among Twenty genotypes (Tentative) with respect to 10 selected traits. Genetic divergence (D^2) between two genotypes is given by the formula:

$$D^2 x = \sum_{i=1}^p \sum_{j=1}^p (\lambda_{ij}) d_i d_j$$

Where, x is the number of metric traits in a point, λ_{ij} is the inverse of the common dispersion matrix λ_{ij} , p is the number of populations / genotypes while d_i and d_j are the difference in the means of two populations for i^{th} and j^{th} characters.

The computation of D^2 using this formula gets complicated and laborious when more number of mutually correlated characters is involved in divergence analysis. So, the character means will be transformed into sets of uncorrelated variables using pivotal condensation of common dispersion matrix following (Rao, 1952). After this transformation the formula for genetic divergence is

$$D^2 = \sum_{i=1} d_i^2$$

Where, d_i is the difference between the transformed values of any two-population means for the i^{th} character. The relative contribution of individual character towards the genetic divergence was assessed from rank average.

3.6.5.1. Grouping of genotypes into different clusters:

Grouping of genotypes into different clusters was accomplished following Tocher's method. Usually, a cluster is defined as a group of populations per clusters such that any two populations belonging to the same cluster should on average, show a smaller D^2 than those belonging to two different clusters. A simple device suggested by Tocher (Rao, 1952) for construction of clusters is to start with two most closely related populations (having the smallest D^2) and then find a third one which has small average D^2 from the first two and so on. At certain stage when it is felt that after adding a particular population there is an abrupt increase in the average D^2 , then that population is not added to the cluster. Similarly, construction of 2nd, 3rd and other clusters are formed till all the populations are included in one or the other cluster.

3.6.5.2. Average intra- and inter-cluster distance

For the measure of intra-cluster distances, the formula $\Sigma D_i^2 / n$ will be used, where ΣD_i^2 is the sum of distances between all possible combinations (n) of populations (genotypes) included in a cluster.

For calculating inter-cluster distance, the formula $D_i^2 / n_i n_j$ was used; where D_i^2 is the sum of all possible pair wise D^2 values between the individuals of one cluster with that of others, n_i is the number of population in cluster 'i' and n_j is the number of population in cluster 'j'.

3.6.6. Stability analysis

3.6.6.1 Stability analysis using Eberhart and Russell model

In the estimation of phenotypic stability, regression analysis has proved to be a valuable technique for assessing the response of various genotypes under changing environmental conditions. In 1966, Eberhart and Russel made improvement in stability analysis by partitioning the genotype-environment

interaction of each genotype into two parts namely, (i) slope of the regression line and (ii) deviation from the regression line. They used the following model to study the stability of genotypes under different environments.

$$Y_{ij} = \mu + \beta_i I_j + d_{ij} \quad (i = 1, 2, \dots, g \text{ and } j = 1, 2, \dots, e)$$

Where,

- Y_{ij} = Mean performance in j^{th} environment of i^{th} genotype
 μ = General mean of genotypes over environments
 β_i = Response of i^{th} genotype measured by coefficient regression i changing environment.
 i_j = Environmental index, as the deviation of the mean of all the genotypes from overall mean at a j^{th} environment

$$I_j = \frac{\sum I Y_{ij}}{t} - \frac{\sum Y_{ij}}{ts} \quad \text{with } \sum I_j = 0$$

d_{ij} = regression deviation in environment j of genotype i .

3.6.6.2 Estimation of parameters of the stability:

- a) The coefficient of regression (β_i) is given by formula:

$$\beta_i = \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

Where,

$\sum_j Y_{ij} I_j$ is the products sum

$\sum_j I_j^2$ is the total SS of environmental index

- b) Mean ($S^2 d_i$) from linear regression is considered as

$$S^2 d_i = \frac{\sum_j s^2_{ij}}{(S-2) \quad r}$$

Where,

$$\sum_j s^2_{ij} = \left[\sum_j Y^2_{ij} - \frac{Y^2_{\dots i}}{t} \right] - \frac{(\sum_j Y_{ij} I_j)^2}{\sum_j I_j^2}$$

and

$S^2 e$ = pooled error estimation

T = No. of

treatments/genotypes

S = No. of environments

Environmental index (I_j) Estimation:

I_j is given by:

$$I_j = \frac{\sum_j Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{ts}$$
$$= \frac{\text{Total of all genotypes at jth location}}{\text{Number of genotypes}} - \frac{\text{Grand total}}{\text{Total number of observations}}$$

3.6.6.3. For each genotype coefficient of regression (b_i) calculated as:

$$b_i = \frac{\sum_j Y_{ij}}{\sum_j I_j^2}$$

Where,

- b_i = regression coefficient
Y_{ij} = matrix value found from of 3 replications
mean
I_j = environmental index

3.6.6.4. Computation of S²_d:

It is possible in analysis of regression to divide the dependent variable (Y) variance into the two portions, the one which explains variables (variance due to regression) of dependent and independent and linearity between them and the other which explicates the variance owing to deviations from linearity. Representatively,

$$\sigma^2_y = \sigma^2_{\text{regression}} + \sigma^2_{\text{deviation from regression}}$$

Calculation of the variance of averages over diverse environments was obtained as below:

$$\sigma^2 V_i = \sum_j Y_{ij}^2 - (Y_i^2/s)$$

Where,

$\sum_j Y_{ij}^2$ = SS of mean of i^{th} genotype over j^{th} environment.

Y_i = SS of mean of i^{th} genotype over j^{th} environment

S = Number of environments.

For a genotype, variance due to regression deviations $\sum_j \sigma^2_{ij}$ is followed as:

$$\sum_j Y_{ij}^2 - Y_i^2 / S - (\sum_j Y_{ij} - I_j)^2 / \sum_j I_j^2$$

Where,

$(\sum_j Y_{ij} - Y_i^2 / S)$ = The variance due to dependent variable and

$(\sum_j Y_{ij} - I_j)^2 / \sum_j I_j^2$ = The variance due to

regression. Because,

$$\frac{(\sum_j Y_{ij} - I_j)^2}{\sum_j I_j^2} = \frac{(\sum_j Y_{ij} - I_j) (\sum_j Y_{ij} - I_j)}{\sum_j I_j^2} = b_i \sum_j Y_{ij} - I_j$$

Where,

$\sum_j Y_{ij} - I_j$ value have been in considered 2 (ii) and b_i values in (2) and

The $\sum_j \sigma^2_{ij}$ values calculated as:

$$\sum_j \sigma^2_{ij} = \sigma^2 V_i - b_i \sum_j Y_{ij} - I_j$$

From $\sum_j \sigma^2_{ij}$, parameter of the stability S^2_{di} genotype each was calculated as;

$$S^2_{di} = [\sum_j \sigma^2_{ij} / (S-2)] - (S^2_e / r)$$

3.6.6.5. Analysis of variance for stability

The analysis of variance partitioned into three main parts.

- SS due to genotypes
- SS due to environment + (genotype x environment).
- Pooled error.

The sum of squares due to genotype x environment is further partitioned into two parts.

- Genotype x environment (linear) S.S. is due to is result of S.S. due to regression. ii. S.S. due to response of deviation from linearity (i.e., S.S. due to pooled deviation).

The latter can be further partitioned into as many components as the number of genotypes with (s-2) degrees of freedom (s represents number of environments).

The analysis of variance for stability parameter was constructed in tabulated form as:

Source of Variation	df	SS	MS
Genotype (G)	(g-1)	$\frac{\sum Y_{i2}}{e} - CF$	MS ₁
Environments (E)	(e-1)	$\frac{\sum Y_{i2}}{g} - CF$	MS ₂
Genotype (G) × Environments (E)	(g-1) (e-1)	$\sum_i \sum_j Y_{ij}^2 - CF - GSS - ESS$	MS ₃
Env. + (Geno. × Env.)	g(e-1)	$\sum \sum Y_{ij}^2 - \frac{Y_{i2}^2}{e}$	MS ₄
Env. (linear)	1	$\frac{(\sum Y_{ij} I_j)^2}{g \sum I_j^2}$	
Gen. × Env. (linear)	(g-1)	$\sum \left[\frac{\sum Y_{ij} I_j^2}{\sum I_j^2} \right] - \left[\frac{\sum Y_{ij} I_j^2}{\sum I_j^2} \right]$	MS ₅
Pooled deviation	g(e-2)	$\sum \sum Y_{ij}^2$	MS ₆
Pooled error	e(r-1) (g-1)		MS ₇

Where,

g = no. of genotypes

s = no. of environments

r = no. of replications

GSS = SS due to genotype

ESS = SS due to environment

S.S. caused by genotypes, environment, and G×E were taken into consideration for calculation of pooled error;

The pooled error M.S calculated as;

$$\frac{(n^1 - 1)(\text{M. S. error } L^1) + \dots (n_s - 1) (\text{M. S. errors})}{(n^1 - 1) + (n_2 - 1) + \dots + (n_s - 1)}$$

Where,

M.S. error Ls = Average SS due to error in sth
environment n₁ - 1 = Error d.f. in
environment1 n₂ - 1 = Error d.f. in
environment2

3.6.6.6. Test of significance:

- The variance significance amongst varieties were confirmed in compared to the MSS owing to interaction of G x E (MS3). The genotypical differences were also confirmed in contradiction of overall deviation (MS6).
- The G x E MS3) is verified in contrast to effective total error.
- The components; environment (linear), G x E (linear) is verified contrary to total deviation (MS6).
- Pooled deviation is verified in contrast to effective overall error (PE/r)
Individual linear deviation regression was calculated by;

$$F = \frac{[(\sum_j \sigma^2_{ij}) / (S-2)]}{\text{Pooled error}}$$

- Genotypes which are Stable i.e., significance test for regression coefficient
A genotype is stable; with coefficient of regression1 (b_i = 1 or not significantly deviated from1) and not significantly deviated from 0 (S²d_i = 0).

$$T \text{ test } b_i = \frac{|b_i - 1|}{S.E.(b_i)}$$

Where,

$$SE \ b_i = \sqrt{\frac{MSS \text{ due to pooled deviation}}{\dots}}$$

$$\frac{\sum_j I_j^2}{t}$$

The bi values significance was confirmed by 't' test as compared to unity:

$$t \text{ test } b_i = \frac{b_i - 1}{S.E.(b_i)}$$

$$\text{Average of } b_i = \sum_i b_i / t$$

Average of population and standard error are calculated by;

$$\text{Population mean } (\mu) = \frac{\text{Grand total}}{\text{No. of observations}}$$

$$S.E. (\text{Mean}) = \frac{\text{M.S. due to pooled deviation}}{\text{Number of environments} - 1}$$

3.6.6.7. Stable genotypes

1. Genotypes with high/ desirable mean value.
2. A genotype with deviation not significantly deviating from zero to said to be stable.
3. A genotype with unit regression coefficient ($b=1$) (not significantly deviating from 1) is said to be average responsive-suitable for all environment.

A genotype with significant b value ($b>1$) is said to be highly responsive suitable for favorable environments.

3.6.6.8. Stability analysis using AMMI:

The chickpea genotypes were subjected to AMMI analysis which is a combination of analysis of variance and multiplication effect analysis. Briefly, analysis of variance is used to partition variance into three components: genotype deviations from the grand mean, environment deviations from the grand mean and GE deviations from the grand mean. Subsequently, multiplication effect analysis has been used to partition GE deviations into

different interaction principal component axes (IPCA), which have been tested for statistical significance through ANOVA.

The AMMI model (Rao and Prabhakaran, 2005) for T genotypes and S environments/locations is below:

$$Y_{ij} = \mu + g_i + e_j + \sum_{n=1}^{n'} \lambda_n \alpha_{in} \gamma_{jn} + \theta_{ij}$$

$$\theta_{ij} \sim N(0, \sigma^2); i=1, 2, \dots, T; j=1, 2, \dots, S$$

Where,

Y_{ij} = mean yield of i^{th} genotype in the j^{th} environment/location

μ = general mean

g_i = i^{th} genotypic effect

e_j = j^{th} location effect

λ_n = eigen value of the IPCA axis n

α_{in} and γ_{jn} are the i^{th} genotype j^{th} environment PCA scores for the axis n

θ_{ij} = residual

n' = number of PCA axes retained in the model

The residual combines the PCA scores from the $N - n'$ discarded axes

where $N = \min(T-1, S-1)$. The other constraints in the model (I) are

$$\sum_{i=1}^T \alpha_{in}^2 = \sum_{j=1}^S \gamma_{jn}^2 = 1 \forall n;$$

$$\sum_{i=1}^T \alpha_{in} \alpha_{in}^* = \sum_{j=1}^S \gamma_{jn} \gamma_{jn}^* = 0, n \neq n^*$$

and $\lambda_1 > \lambda_2 > \dots > \lambda_{n'} > 0$

The AMMI model in (1) can be re-parameterized as

$$Y_{ij} = \mu + g_i + e_j + Z_{ij}$$

Where,

$$Z_{ij} = \sum_{n=1}^{n'} \lambda_n \alpha_{in} \gamma_{jn} + \theta_{ij}$$

Let the estimate of interaction in the (i, j) the cell Z_{ij} be $\hat{Z}_{ij} = Y_{ij} - \hat{\mu} - \hat{g}_i - \hat{e}_j$ using matrix notation, denote $Z = (\hat{Z}_{ij})$ a matrix of order $T \times S$. Now, the estimates of the parameters of model are:

$\hat{\lambda}_n$ = the non-zero eigen values of $Z Z'$ (in descending order)

$\hat{\alpha}_{in}$ = the principal components of the row sum of squares and cross product matrix $Z Z'$

$\bar{y}_{jn}$ = the principal components of the columns of the sum of squares and cross product matrix $Z Z'$ Using these we can write

$$\hat{Z}_{ij} = \sum_{n=1}^N \hat{\lambda}_n \hat{\alpha}_{in} \hat{y}_{jn}$$

It follows that, $\alpha_{in}^* = \lambda_n^c \hat{\alpha}_{in}$ is the i^{th} genotype PCA score for the n^{th} axis, and

$$\hat{y}_{jn} =$$

$\lambda_n^{1-c} \hat{y}_{jn}$ is the n^{th} PCA score of the j^{th} environment; where c is a scaling constant varying

between 0 to 1.

Also, using factor analytic decomposition, Z may be written as

$$Z = ADB'$$

Where,

A is $T \times N$ orthonormal matrix.

D is $N \times N$ diagonal matrix with elements $\lambda_1 > \lambda_2 > \dots > \lambda_n > 0$, B is $N \times S$ orthonormal matrix, N is the rank of Z . The matrices A , D and B of equation (4) can be obtained from the eigen vectors and eigen values of $Z'Z$ of the order $T \times T$. The matrix A consists of the eigen vectors (principal components, α_{in}) of $Z Z'$ and the diagonal matrix D with square root of eigen values as diagonal elements of ZZ' . The matrix B consists of the eigen vectors (principal components, y_{jn}) can be obtained by solving $B = Z A' D^{-1}$. For many practical situations, the number of PCA axes to be retained is determined by testing the mean square of each axis with the estimate of residual through F -statistics (Gollob, 1968 and Gauch, 1988). The mean sum of squares of each PCA axis is equal to the ratio of square of the corresponding eigen value and the degree of freedom of each axis obtained as $T+S-1-2n$.

3.6.6.9. Method for retaining number of IPCA:

The Gollob (1968) approximate F -test assumes that $n\hat{\lambda}_m^2/\sigma^2$ is distributed as a chi-square variable and he suggests using the statistic:

$$F = \hat{\lambda}_m^2 / (f_1 MS(\text{Error mean}))$$

Against an F -distribution with $f_1 = T+S-1-(2m)$ and $TS(n-1)$ degrees of freedom, or $T(S-1)(n1)$ degrees of freedom if blocks are present, to test the m -

th multiplicative term of the model for significance. By contrast, Cornelius *et al.* (1992) uses

$$F_{R,m} = (SS(GEI))/(f_{2MS}MS(Error\ mean))$$

Against an F -distribution with $f_2=(T-1-m)(S-1-m)$ and $TS(n-1)$ degrees of freedom, or $T(S-1)$ ($n-1$) degrees of freedom if blocks are present, to test significance of lack of fit of the m -term model.

3.6.6.10. Stability analysis using GGE Biplots:

$G \times E$ data for any character is generally presented as follows

$$Y = \begin{matrix} & \begin{matrix} E_1 & E_2 & \dots & E_{(S-1)} & E_S \end{matrix} \\ \begin{matrix} G_1 \\ G_2 \\ \vdots \\ G_{(T-1)} \\ G_T \end{matrix} & \begin{bmatrix} y_{11} & y_{12} & \dots & y_{1(S-1)} & y_{1S} \\ y_{21} & y_{22} & \dots & y_{2(S-1)} & y_{2S} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ y_{(T-1)1} & y_{(T-1)2} & \dots & y_{(T-1)(S-1)} & y_{(T-1)S} \\ y_{T1} & y_{T2} & \dots & y_{T(S-1)} & y_{TS} \end{bmatrix} \end{matrix}$$

Where,

G denotes genotype and

E denotes environment.

The above data matrix can be optimally approximated by SVD in rank two matrix accordingly. So, the basic model for constructing a GGE biplot from GE data is given by

$$Y_{ij} = \mu + g_i + e_j + \phi_{ij} + \theta_{ij}$$

Where,

Y_{ij} = the average yield of genotype i in environment j

μ = overall or grand mean

$g_i = i^{\text{th}}$ genotypic effect

$e_j = j^{\text{th}}$ location effect

ϕ_{ij} = interaction between g_i and e_j

θ_{ij} = the residual of the model associated with the genotype i in environment j

In recent years, GGE (i.e. grand mean and environment centered) biplot has got wider acceptability and its model is mathematically represented as

$$Y_{ij} - \mu - Y_j = \xi_i \lambda_1 \eta_1 + \xi_i \lambda_2 \eta_2 + \theta_{ij}$$

Where,

Y_{ij} is the average yield of genotype i in environment j

$\bar{Y}_j$ is the average yield over all genotypes in environment j

λ_1 and λ_2 are the singular values for PC₁ and PC₂ respectively

ξ_{i1} and ξ_{i2} are the PC₁ and PC₂ scores, respectively for genotype i

η_{1j} and η_{2j} are the PC₁ and PC₂ scores, respectively for environment j

To display PC₁ and PC₂ in a biplot, the equation is rewritten as

$$Y_{ij} - \mu - \bar{Y}_j = \xi_{i1}^* \eta_{1j}^* + \xi_{i2}^* \eta_{2j}^* + \theta_{ij}$$

Where,

$H\xi$

$\xi_{in}^* = \lambda_n^k \xi_{in}$ and

$\eta_{nj}^* = \lambda_n^{1-k} \eta_{nj}$ with $n = 1, 2$

GGE biplot is generated by plotting ξ_{i1}^* and η_{1j}^* against ξ_{i2}^* and η_{2j}^* .

Though k may take infinite number of values between 0 and 1, only three values 0, 1 and 0.5 are common in use.

3.6.6.11. Construction of GGE biplots using Software:

For the purpose of construction of biplots, we used ‘metan’ package for GGE biplot in R system. ‘Metan’ may be installed from r cran Package after installation of package various types of biplots may be constructed.

3.7. Biochemical tests:

3.7.1. Estimation of chlorophyll

Principle

Among the most important molecules for plant function are the pigments. Plant pigments include a variety of different kinds of molecules, including porphyrins, carotenoids, anthocyanins and betalains. All biological pigments selectively absorb certain wavelengths of light while reflecting others. The light that is absorbed used by the plant to power chemical reactions, while the

reflected wavelengths of light determine the color the pigment. Pigments also serve to attract pollinators.

Procedure

Uppermost fully expanded leaves are detached from at least five representative plants before 12.00 noon when solar PPFD is around 500 $\mu\text{mol m}^{-2}\text{s}^{-1}$.

Chlorophyll content method: -

Acetone extracts method

For determination of the chlorophyll content of leaves the simplest method is to freeze the leaf in liquid N, grind it to a powder, mix with 80% acetone in the dark and then centrifuge or filter. Measure the absorbance (A) of the acetone extract at 663 and 645 nm in a 1 cm path length cuvette.

Non maceration Dimethyl sulphoxide (DMSO) method

Chlorophyll content was estimated by using Dimethyl sulphoxide (DMSO) a solvent following the procedure suggested by Hiscox and Israelstam (1979). Leaf slices weighing 50 mg are transferred to test tubes containing 5 ml of DMSO. The tubes are then incubated at 65°C for 2 hours. Absorbance of the extract is read at 645 and 663 nm using a spectrophotometer. Chlorophyll/content is calculated using the following formula (mg g fresh wt) of leaf tissue.

Calculation

- a) Chlorophyll **a** = $(12.7 \times A_{663}) - (2.69 \times A_{645}) \times \{(v / (1000 \times w))\}$
- b) Chlorophyll **b** = $(22.9 \times A_{645}) - (4.68 \times A_{663}) \times (v / (1000 \times w))$
- c) Total chlorophyll = $(20.2 \times A_{645}) + (8.02 \times A_{663}) \times ((v / (1000 \times w)))$
- d) **w** = fresh wt. of tissue in gram
- e) **v** = volume of extract in millilitre

3.7.2. Protein content:

For protein analysis seeds from each individual environment were collected after harvest and tested for moisture content. The nitrogen content of the winged bean genotypes was determined by the Kjeldahl method using a KEL PLUS Distillation Unit which involves the following three steps: -

Reagents:

- a) Concentrated Sulphuric acid (Conc.H₂SO₄)
- b) Catalyst Mixture (K₂SO₄ +CuSO₄): 5:1
- c) 40% NaOH
- d) 4% Boric Acid
- e) Indicator-Mixed Indicator or Methyl red solution (2 or 3 drops)

Procedure

1.Digestion

Digestion mixture which contains 0.5 gm of grinded seed sample, 10 ml of Conc.H₂SO₄, 5gm of potassium sulphate with 1 ml of copper sulphate as catalyst mixture of K₂SO₄ +CuSO₄ (5:1) was prepared in the digestion tube. The digestion mixture tube was kept in the KEL PLUS machine for digestion. Digestion was continued till the mixture turn into bluish green or greyish white. Then digestion tube was allowed for cooling.

2. Distillation

Distillation involves the separation and isolation of nitrogen from the digested mixture. The volume was made up to the mark using distilled water and mixed. Measured aliquot (10 ml) was taken in a distillation flask and 40% NaOH added into the digestion tube through alkali loading tube. On heating, the ammonia is distilled out and trapped in 4 % boric acid (25ml) mixed with indicator (4 drops of bromoceresolgreen and methyl red) in conical flask as trapping medium. Once the distillation starts, light pink color of seed sample change into sky blue colour.

3. Titration

The determination of nitrogen amount present in the conical flask is done by titration with 0.1N of H₂SO₄. A blank sample was also run along with the sample. Sky bluish color solution turns into pink color which indicates completion of titration.

$$\text{Nitrogen (\%)} = \frac{14 \times \text{Titre value} \times 0.1N \times 100}{\text{weight of sample(g)} \times 1000}$$
$$\text{Crude protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

3.7.3. Oil content:

The oil content for each genotype was estimated on dry seed basis by using SOCS PLUS machine *i.e.* automatic solvent extraction system, using the standard procedure.

Reagents

“Acetone (Boiling point 80°C)”

Procedure

After rinsing all the beakers, they were placed in the oven for 10 minutes at 100°C temperature for drying. Samples were also kept in the oven for drying and for maintaining optimum moisture content in the samples. These beakers were then placed into desiccators for about 10 minutes to bring them into room temperature. Now, empty beaker weight *i.e.* initial beaker weight (IBW) was taken as W₁. Thimbles were inserted into the thimble holder which were placed on beaker. After that 1gm of grinded seed sample (SW) was taken and placed into the thimble. 80 ml of solvent (acetone) was poured in the beaker. Now, all the beakers (4) along with the sample and solvent were loaded in the system and system were switched on after setting solvent's boiling temperature *i.e.* 80°C (The boiling temperature could be more than that of solvent's maximum boiling point). This boiling process was left for 60 minutes as first cycle. After the process time, the second cycle was started by increasing the temperature to recovery temperature *i.e.* 120°C for 30 minutes. After completing the second cycle, rinsing of thimble is done with acetone to collect the remaining fat that

may present in the sample or in the thimble. Now, all the beakers from the system were taken out and all the thimbles from the beaker were removed. Beakers were kept in hot air oven at 100°C for 20-30 minutes to remove the excess acetone if present in the beaker. After, cooling in the desiccator now the final beaker weight (FBW) as W_2 was taken. After, substituting SW, W_1 and W_2 in the given formula, the percentage of Oil present in the sample was calculated.

$$Oil (\%) = \frac{W_2 - W_1}{SW} \times 100$$

Where,

W_1 =Initial beaker weight

W_2 =Final beaker weight

SW=Sample Weight

Plate 3.1 Variability among the genotypes seeds of winged bean used in present study.

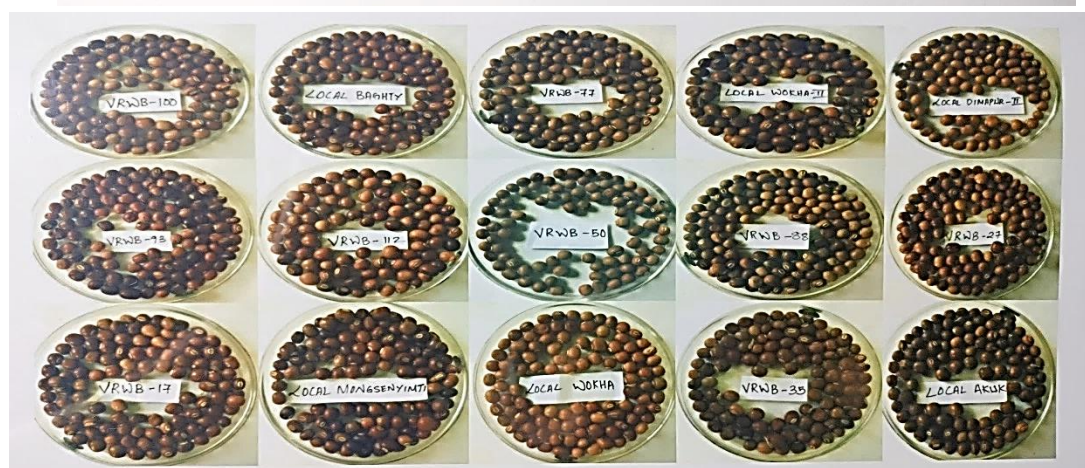
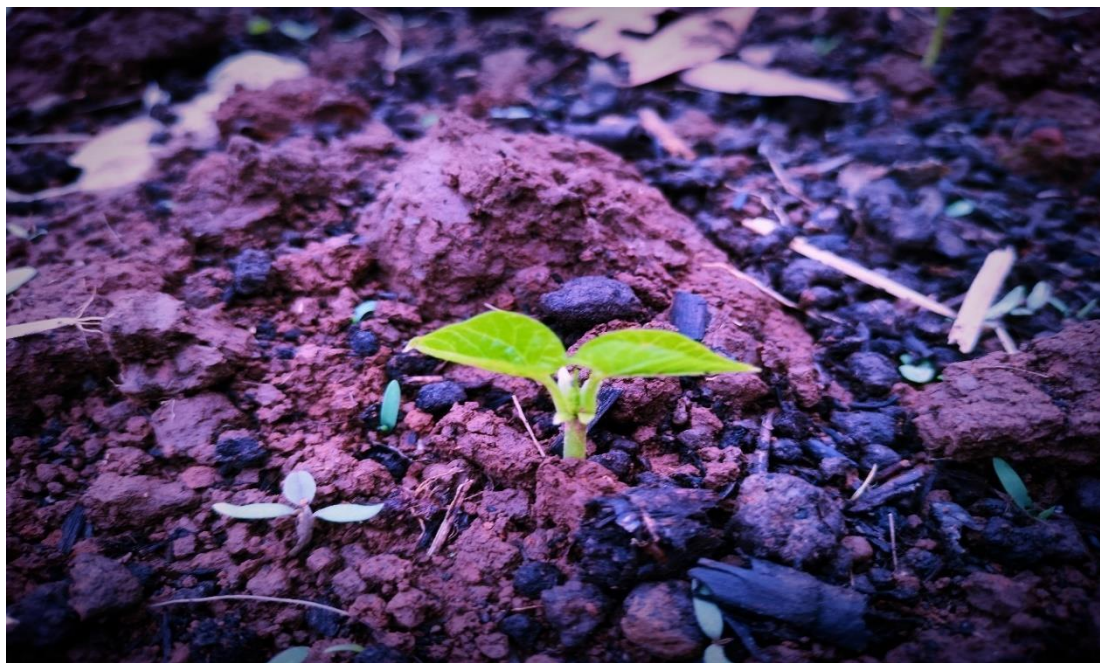


Plate 3.2 Growth stages of winged bean.

1 Germination stage



2. Growth stage 10 DAS



3 Flowering stages

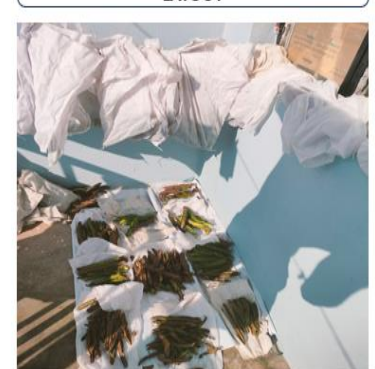


4 Podding Stage





A person wearing a blue t-shirt under a red and blue plaid shirt is holding a long, green chili pepper in their hands. They are standing in a field with green plants in the background. The person has glasses hanging from their shirt and a watch on their left wrist.



5. REPRESENTATION OF CROP DATA COLLECTION DURING PRE HARVEST AND POST HARVEST MANAGEMENT



6. REPRESENTATION OF THE PLOT DURING DATA COLLECTION



7. REPRESENTATION OF DIFFERENT PARTS OF PLANT AND ITS LIFE STAGES





8. REPRESENTAION OF RESEARCH WORK DURING OIL CONTENT ANALYSIS



9. REPRESENTAION OF RESEARCH WORK DURING PROTEIN ANALYSIS



10. REPRESENTATION OF CHLOROPHYLL ESTIMATION ON 40 WINGED BEAN GENOTYPE



CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Results obtained from the experiment conducted “**Genotype x environment interaction analysis and variation studies in winged bean [*Psophocarpus tetragonolobus* (L.) DC.]**” during *summer* 2022 and 2023 in six different environments *i.e.*, 16th March in 2022-23 (E1), 26th March in 2022-23 (E2), 5th April in 2022-2023(E3), 16th March in 2023-24 (E4), 26th March in 2023-24(E5), and), 5th April in 2023-2024 (E6) are interpreted on the basis of statistical analysis and documented graphically wherever, necessary. The entire experimental results obtained from the present investigation entitled has been presented under the following heads:

- 4.1 Characterization of some of the qualitative traits in the various genotypes of winged bean
- 4.2 Analysis of Variance
- 4.3 Mean performance of genotypes for sixteen morpho-physiological and quality traits
- 4.4 Estimates of component of Genetic parameters
- 4.5 Correlation coefficient analysis
- 4.6 Path coefficient analysis
- 4.7 Estimation of genetic divergence
 - i.Morphological Divergence
- 4.8 Stability analysis
 - i.Eberhart and Russel model (1966)
 - ii.AMMI model

4.1. Characterization of some of the qualitative traits in the various genotypes of winged bean

Ten qualitative characters were studied and these characters were statistically analysed.

4.1.1. Stem colour

The colour of the all experimented 40 genotypes were found to be green in colour.

4.1.2. Colour of winged pod.

The colour of winged pod was also found to be green among all the genotypes.

4.1.3. Pod surface texture

The texture of the surface was found to be medium for most of the genotypes except for Local Akuk and VRWB-50 which showed rough texture while VRWB-24, VRWB-26, VRWB-32, Local Pangti-2, Local Dimapur-2, VRWB-77, VRWB-93, VRWB-100, VRWB-104, VRWB-112 and Local Mongsenyimti found to have smooth pod texture.

4.1.4 Pod shape

The suture for the winged bean has been found to be rectangular in shape for most of the genotypes except for the genotypes *viz.*, NUWB-3, VRWB-27, Local panngti-1, Local Pangti-2, Local wokha-1, VRWB-59, Local Dimapur-3, Local Baghty, VRWB-93, VRWB-100 and VRWB-104 found to have flat-sutures structure among them.

4.1.5 Presence of pod specks

All the 40-winged bean genotypes showed presence of pecks among them

4.1.6 Leaflet shape

Different types of leaflet shapes has been found among the 40 genotypes which include ovate as prominent among the genotypes *i.e.*, VRWB-23, NUWB-1, VRWB-36, VRWB-45, Local Dimapur-2, VRWB-50, VRWB-59, VRWB-75, VRWB-77, VRWB-85, VRWB-88, VRWB-93, VRWB-104, Local

Mongsenyimti, VRWB-112, VRWB-116 and NUWB-2 followed by deltoid shape in the genotypes Local wokha-2, Local Suchonoma, VRWB-4, Local Peren, Local Medziphema, VRWb-24, VRWb-32, VRWb-35, Local Pangti-1, Local Dimapur-1, Local Pangti-2, Local Akuk, VRWb-54, Local Baghty and VRWB-100 lastly Lanceolate shape has been recorded among the VRWB-2, NUWB-3, VRWB-26, VRWB-27, Local Wokah-1, Local Dimapur-3 and VRWB-115.

4.1.7 Pod Colour

All the pod colours has appeared to be green in colour except for the VRWB-93 which showed predominantly green colour in the early stages followed by the purple on its edges during maturity.

4.1.8. Calyx colour

All the calyx colour has been found to be green in colour among 40 genotypes

4.1.9. Corolla colour

The corolla colour of the 40-winged bean genotype showed purplish blue colour as a majority similar results were found with Yadav (2021), except for the VRWB-85 which showed white coloured corolla in the E4 environment (summer 2023) followed by purple colour corolla for the genotypes Local Baghty, VRWB-104 and Local Mongsenyimti has been found.

4.1.10. Seed colour

Different types of seed colour have been found among 40 genotypes which shows maximum frequency of colour brown in most of the genotypes excluding VRWb-20 and VRWB-54 showed cream-coloured seeds, Local Suchonoma, VRWB-23 and VRWB-77 showed brown black seed colour and two genotypes VRWB-88 and VRWB-35 showed purplish black seed colour.

4.2 Analysis of Variance of 16 characters for Winged bean Genotype in Timely, Late and Very Late sown Condition (E1+E4, E2+E5, and E3+E6) Sown condition

Analyses of variance for all the sixteen characters in winged bean under recommended date of sowing is presented in the Table 4.1.

Under timely, late and Very-late sown conditions, mean data for sixteen traits were subjected to analysis of variance (ANOVA). The mean sum of squares due to genotypes were found significant for all the traits under study (Table 4.1) which indicates that considerable amount of variability was present among the genotypes. Hence, there is scope for inclusion of promising genotypes in breeding program for yield and its component traits.

A perusal of table revealed that the genotypes exhibited highly significant differences among themselves for all the sixteen characters viz., plant height (m) (PH) , days to first flowering (DFF), days to pod initiation (DPI), days to maturity (DM), days to 50% flowering (DFPP), pod length (cm) (PL), Pod width (cm) (PW), dry pod weight (g) (DPW), tuber weight (g) (TW), tuber diameter(cm) (TD), tuber length(cm) (TL), pod yield per plant (g) (PYPP), number of pod per plant (NPPP), number of seed per pod (NSPP), 100 seeds weight (g) (SI) and seed yield per plant(g) (SYPP).

Table 4.1: Pooled Analysis of variance for Sixteen quantitative characters for Winged bean Genotype in Timely, Late and Very Late sown Condition (E1+E4, E2+E5, and E3+E6) Sown condition

Source of Variation s	Replicate			Environments			Interactions			Treatments			Error		
	Timel y	Late	Vey late	Timely	Late	Vey late	Timel y	Late	Vey late	Timely	Late	Vey late	Timely	Late	Vey late
DF	2			1			2			39			195		
PH	0.12	0.10	2.63	51.08***	7.190***	5.334	0.01	0.01	2.75	5.08***	4.250***	4.806***	0.21	0.31	0.10
DFF	59.38	57.37	2.30	163.35***	273.963***	121.510***	1.00	6.88	4.72	1758.83** *	1861.770** *	1713.592** *	80.47	77.03	27.63
DFPF	36.30	83.40	54.51	3673.06***	3748.550** *	3206.751***	13.15	14.3 7	75.83	1847.24** *	1945.458** *	1918.494** *	100.71	98.30	48.58
DPI	12.76	53.77	4.30	222.28***	11.107	222.800***	2.77	9.57	12.13	1718.35** *	2017.677** *	1806.134** *	42.38	46.45	25.35
DM	2.58	148.4 7	17.32	573.44***	15.000	49.241	8.03	32.4 2	16.53	2343.72** *	2308.008** *	2231.781** *	60.67	196.7 3	81.09
PL	0.05	1.58	0.28	17.93***	4.831**	0.011	0.42	0.62	0.32	23.62***	30.059***	36.302***	2.70	2.70	2.55
PW	0.00	0.00	0.02	0.06***	0.003	0.000	0.01	0.01	0.01	0.22***	0.381***	0.525***	0.02	0.03	0.01
DPW	0.03	0.01	0.11	1.95***	0.105	5.174***	0.03	0.05	0.04	4.75***	5.208***	5.103***	0.10	0.08	0.17
TL	0.98	4.97	0.96	114.28***	86.388***	154.369***	0.59	0.37	3.48	299.29***	269.416***	258.841***	6.69	5.63	6.51
TWE	0.90	11.10	4.22	2.58***	2.532	66.940*	6.25	4.97	14.04	1736.67** *	2073.726** *	2141.141** *	10.57	10.80	16.35
TWI	0.09	0.07	0.06	0.002***	0.026*	1.785***	0.00	0.01	0.00	2.36***	1.267***	2.462***	0.02	0.25	0.05
PYPP	238.67	47.92	33.08	18427.89** *	275.590***	5739.979***	3.92	21.3 6	3.62	6442.51** *	6775.718** *	2350.606** *	1230.6 5	483.9 5	194.6 4
NPPP	7.23	1.78	0.11	956.40***	2.139	27.812***	0.02	1.33	0.32	199.00***	316.014***	217.148***	15.23	7.65	3.58
NSPP	0.64	0.28	0.00	5.58***	18.554***	1.719***	0.05	0.19	0.08	10.50***	13.652***	10.250***	1.03	1.61	0.42
SI	1.42	0.24	0.31	114.36***	142.157***	1.166	0.02	0.04	1.04	60.76***	64.436***	59.794***	7.31	6.09	6.12
SYPP	57.23	2.36	47.90	36338.88** *	347.041***	21899.680** *	1.74	0.31	6.65	3882.04** *	6255.621** *	3005.664** *	332.67	313.7 5	145.0 7

*, ** and *** significance at 5 %, 1 % and 0.05 % level, respectively

PH; Plant height (m) , DFF; days to first flowering, DPI; days to pod initiation, DM; days to maturity, DFPP; days to 50% flowering, PL; Pod length (cm), PW; Pod width (cm), DPW; Dry pod weight (g), TWE; Tuber weight (g), TWI; Tuber diameter(cm), TL; Tuber length(cm), PYPP; Pod yield per plant (g), NPPP; Number of pod per plant,, NSPP ; number of seed per pod, SI ; 100 seeds weight (g), SYPP; seed yield per plant (g).

4.3. Mean performance of genotypes for timely sown and late sown conditions over sixteen quantitative traits: -

The mean performance of forty genotypes for all the traits under study has been presented in Table 4.2. It is evident that various attributes showed presence of significant variability but their magnitude varied from one character to another.

In general, a wide range of variation were found among all the forty genotypes in sixteen characters as presented in Table 4.3, exhibited considerably wide range of variations among genotypes for undertaken traits. The mean performance of genotypes for all the traits under study has been presented in Table 4.2. In general, a wide range of mean values between the genotypes were found for the respective traits. Trait wise mean performances of the genotypes is being discussed here.

Table 4.2: Mean performance of 40-winged bean genotypes for Timely, late and very-late sown condition.

S. No.	Genotypes	Plant height(m)			Days to first Flowering			Days to 50% Flowering			Days to Pod initiation			Days to Maturity			Pod Length(cm)		
		Timel y	Lat e	Vey late	Timel y	Late	Vey late	Timel y	Late	Vey late	Timel y	Late	Vey late	Timel y	Late	Vey late	Timel y	Late	Vey late
1	LOCAL WOKHA-2	6.25	6.7 7	6.24	96.50	100.2 7	98.15	126.00	130.0 6	129.75	97.50	104.5 0	102.49	202.17	200.6 7	192.61	17.06	17.5 1	17.98
2	LOCAL SUCHONOMA	6.07	6.7 2	6.23	99.00	100.7 7	102.55	139.38	138.2 8	137.24	105.17	109.5 8	109.48	202.67	200.8 3	194.28	20.60	21.4 6	22.08
3	NUWB-4	6.64	7.7 7	7.03	117.50	114.0 0	114.57	146.48	145.4 4	143.53	123.67	118.1 9	121.78	212.00	204.0 0	209.89	16.74	16.2 4	16.43
4	LOCAL PEREN	4.52	5.1 7	4.45	123.50	121.9 2	121.95	153.46	151.5 9	153.83	126.00	126.7 2	126.25	210.33	214.8 3	207.34	17.11	17.6 5	17.43
5	LOCAL MEZDIPHEMA	5.34	5.8 7	5.61	86.67	89.82	87.61	121.36	119.6 8	122.67	91.67	95.33	92.53	206.67	210.1 7	206.00	18.85	19.9 0	20.46
6	VRWB-17	6.98	7.8 7	6.96	58.00	56.73	58.94	83.37	80.25	83.00	62.83	54.18	63.80	145.17	143.6 7	153.17	16.13	15.7 7	15.43
7	VRWB-20	5.04	6.2 3	5.83	62.00	61.51	62.29	92.00	90.09	94.16	67.00	61.62	67.14	147.83	146.5 0	142.22	18.13	19.3 9	19.74
8	VRWB-23	5.65	6.6 2	5.93	76.17	78.39	78.29	113.95	118.9 2	120.00	80.67	88.21	81.93	171.83	173.8 3	176.95	14.30	15.2 7	15.49
9	VRWB-24	5.34	6.8 5	5.38	85.50	83.77	80.21	108.38	110.2 8	107.41	89.50	86.07	85.74	155.00	153.1 7	154.50	14.47	14.3 8	14.44
10	NUWB-3	6.19	6.9 3	6.16	98.67	100.9 3	100.83	138.64	141.6 2	139.11	105.83	112.3 5	109.83	214.67	212.5 0	215.61	14.47	14.3 5	14.75
11	VRWB-26	5.62	6.1 3	5.79	81.67	80.91	86.31	131.91	136.8 1	133.50	88.33	96.76	91.39	194.17	191.0 0	192.06	16.03	15.9 3	16.42
12	VRWB-27	7.28	7.9 3	7.02	61.33	62.58	61.62	89.76	90.41	87.74	68.67	62.93	68.20	142.17	145.8 3	137.11	14.11	14.1 7	13.65
13	VRWB-68/NUWB-1	6.77	7.2 4	6.67	108.33	111.2 5	111.34	148.98	145.3 0	146.99	111.67	114.4 7	115.70	198.00	197.5 0	195.50	16.61	16.7 5	16.35
14	VRWB-32	4.32	5.2 3	4.80	91.83	94.10	93.36	133.08	130.8 5	130.00	97.50	103.2 1	100.09	183.33	182.6 7	182.00	16.02	15.8 6	16.13
15	VRWB-35	6.14	6.4 5	6.26	91.83	85.96	90.17	129.02	128.3 8	128.41	94.67	91.18	91.65	194.67	183.6 7	181.45	14.63	14.4 1	14.53
16	VRWB-36	6.52	7.2 7	6.78	99.67	101.2 0	101.23	136.12	137.0 3	140.00	102.67	102.7 2	105.14	186.33	188.1 7	189.89	14.62	15.1 8	15.37
17	LOCAL PANGTI-1	5.15	6.2 0	5.68	112.83	110.0 1	108.98	143.50	145.9 3	150.50	119.67	109.6 9	118.32	206.83	208.3 3	204.00	16.30	16.7 9	16.96
18	LOCAL DIMAPUR-1	6.07	6.6 2	6.72	102.00	99.20	104.49	135.64	135.4 5	137.60	105.67	113.3 4	106.19	198.00	196.8 3	194.89	18.95	19.5 0	19.91
19	VRWB-45	5.45	5.9 0	5.63	96.33	98.45	95.37	123.34	129.7 4	128.50	102.33	113.1 5	106.95	195.50	192.0 0	189.56	15.21	15.0 4	15.21
20	LOCAL PANGIT-2	4.53	5.1 3	4.54	121.67	122.2 8	122.60	144.00	144.5 4	149.50	124.67	123.5 2	126.70	199.50	198.3 3	201.83	19.15	19.3 7	19.64
21	LOCAL DIMAPUR-2	5.51	6.0 0	5.71	84.50	82.30	80.95	104.64	104.6 4	108.11	87.67	82.66	84.14	171.67	168.6 7	166.17	19.01	19.3 7	19.57

22	LOCAL AKUK	6.56	6.7 7	6.53	88.50	85.09	84.10	117.01	111.1 9	116.05	93.50	88.79	88.86	174.17	177.5 0	174.22	13.61	13.8 9	14.16
23	VRWB-50	4.64	5.2 4	4.74	96.00	95.91	90.39	125.59	124.5 9	121.50	100.33	98.75	97.91	187.50	187.3 3	179.67	14.61	14.2 9	14.37
24	VRWB-54	4.50	5.0 5	4.56	88.67	88.90	86.17	115.14	113.7 8	113.40	91.83	91.37	88.84	162.33	165.3 3	160.61	14.81	14.6 5	15.15
25	LOCAL WOKHA-1	4.28	5.0 2	4.57	100.67	101.1 2	97.40	129.68	130.9 1	130.30	105.33	102.0 7	103.42	182.50	186.0 0	184.78	17.43	17.3 1	17.43
26	VRWB-59	4.09	4.9 6	4.20	112.33	114.4 3	109.26	136.02	137.7 3	135.00	116.33	113.9 5	113.41	184.83	185.6 7	189.06	13.74	13.2 3	13.19
27	LOCAL DIMAPUR-3	7.13	7.6 1	7.29	124.00	125.2 9	124.78	148.48	151.5 0	151.00	129.67	124.9 6	130.39	192.67	197.1 7	194.50	21.72	22.0 1	22.65
28	VRWB-75	4.56	5.2 3	4.78	97.67	97.20	100.54	130.00	131.8 6	129.50	100.50	113.5 7	100.66	191.33	189.1 7	186.39	15.91	16.2 5	16.51
29	VRWB-77	6.71	6.7 9	7.08	89.50	84.55	87.25	117.28	110.2 1	113.83	93.67	90.66	91.44	168.67	173.0 0	168.39	13.76	13.2 8	13.22
30	VRBW-85	6.26	6.6 5	6.49	89.17	90.38	92.20	118.56	118.8 3	118.00	93.67	97.43	96.59	175.50	170.3 3	176.06	14.57	13.6 6	13.52
31	VRWB-88	5.07	5.6 9	5.11	95.50	91.72	97.38	125.50	126.0 7	126.50	99.50	113.2 9	100.25	181.50	181.8 3	177.39	14.41	14.4 3	14.27
32	LOCAL BAGHTY	5.32	5.9 3	5.80	89.50	91.73	92.59	120.43	120.0 4	118.50	93.00	99.85	96.21	167.67	165.1 7	165.39	16.29	16.2 9	16.07
33	VRWB-93	5.00	5.9 4	5.30	71.67	68.86	69.05	95.45	98.07	95.00	74.67	68.38	72.50	151.83	149.1 7	145.83	15.35	15.8 0	16.23
34	VRWB-100	4.39	5.4 9	4.88	75.50	76.44	76.63	103.16	103.9 0	103.50	79.67	81.88	80.77	153.00	154.5 0	157.45	17.83	18.2 6	18.48
35	VRWB-104	5.05	5.9 3	5.44	103.83	105.4 2	104.62	131.50	131.1 4	135.43	105.50	112.0 3	107.93	188.83	191.5 0	173.56	18.67	18.5 9	18.67
36	LOCAL MONSENTI	4.29	5.4 0	4.33	104.50	107.7 0	101.12	128.97	133.5 6	130.00	106.00	117.2 5	102.81	182.00	177.3 3	181.89	15.57	15.9 8	16.35
37	VRWB-112	5.18	5.8 0	5.30	75.83	76.90	76.59	110.04	111.3 6	108.00	79.50	79.64	78.95	155.67	158.5 0	155.33	15.54	15.7 8	15.84
38	VRWB-115	3.97	5.4 0	4.32	87.83	88.60	90.33	114.69	112.8 3	117.71	90.50	86.80	90.64	166.34	162.3 3	164.72	15.57	15.2 2	14.77
39	VRWB-116	5.67	6.8 4	6.11	125.33	128.7 0	124.85	149.65	153.0 1	149.00	127.83	124.4 7	129.79	194.83	197.1 7	192.56	15.45	14.9 0	14.61
40	NUWB-2	5.84	6.3 9	6.24	119.50	121.1 4	115.74	146.35	142.2 5	142.00	124.17	121.3 2	123.07	185.50	184.8 3	183.11	18.52	18.7 2	20.76
	Mean	5.50	6.2 2	5.71	94.78	94.91	94.57	125.16	125.4 5	125.64	98.96	99.92	99.25	182.13	181.6 8	179.95	16.30	16.4 2	16.60
	C.V.	8.43	8.9 2	5.43	9.46	9.25	5.56	8.02	7.90	5.55	6.58	6.82	5.07	4.28	7.72	5.00	10.08	10.0 1	9.61
	S.E.	0.19	0.2 3	0.13	3.66	3.58	2.15	4.10	4.05	2.85	2.66	2.78	2.06	3.18	5.73	3.68	0.67	0.67	0.65
	C.D. 5%	0.53	0.6 3	0.35	10.21	9.99	5.99	11.43	11.29	7.94	7.41	7.76	5.73	8.87	15.97	10.25	1.87	1.87	1.82

Table 4.2 Continued.....

S. No.	Genotypes	Pod Width(cm)			Dry pod weight (g)			Tuber length (cm)			Tuber weight (g)			Tuber Width (cm)			Pod Yield/plant		
		Timel y	Lat e	Vey late	Timel y	Lat e	Vey late	Timel y	Late	Vey late	Timel y	Late	Vey late	Timel y	Late	Vey late	Timel y	Late	Vey late
1	LOCAL WOKHA-2	2.45	2.43	2.58	5.28	5.45	5.31	31.82	28.69	29.67	31.26	33.14	31.44	3.05	2.60	2.85	189.58	181.07	185.11
2	LOCAL SUCHONOMA	2.47	2.35	2.35	5.31	5.30	5.92	22.51	22.40	23.78	46.64	48.00	50.18	2.34	1.95	2.53	186.55	166.44	153.54
3	NUWB-4	2.57	2.50	2.53	5.36	4.67	5.07	29.52	28.41	30.83	46.75	43.88	44.09	1.58	1.72	1.48	172.95	142.22	149.97
4	LOCAL PEREN	2.59	2.30	2.65	4.68	4.54	4.40	27.31	26.12	23.13	48.86	50.83	47.61	2.06	2.09	2.23	197.63	155.12	161.35
5	LOCAL MEZDIPHEMA	2.38	2.57	2.57	6.20	6.36	6.99	32.06	31.39	32.26	29.36	30.33	31.83	2.16	2.21	2.34	210.14	179.64	167.58
6	VRWB-17	2.58	2.40	2.70	6.82	6.19	6.32	20.33	20.65	21.40	37.20	34.41	34.89	1.92	2.17	2.15	260.52	238.17	179.16
7	VRWB-20	2.92	2.55	3.12	6.00	6.34	5.88	20.80	20.54	19.36	34.37	36.26	33.66	2.02	1.89	2.21	258.64	240.23	200.61
8	VRWB-23	2.43	2.63	2.35	4.44	4.60	5.25	34.57	34.67	34.99	47.33	48.11	50.59	1.35	2.36	1.46	191.19	167.00	159.22
9	VRWB-24	2.98	2.77	2.72	5.89	5.57	6.01	17.43	17.71	18.09	27.02	25.07	25.49	3.53	2.61	3.55	176.93	167.32	150.29
10	NUWB-3	2.35	2.58	2.38	3.67	4.24	4.00	39.52	39.30	36.45	33.23	34.82	32.88	2.02	2.16	2.05	142.58	119.47	134.11
11	VRWB-26	2.57	2.45	2.65	4.70	4.72	5.40	20.38	21.29	22.34	39.02	39.85	42.17	2.53	2.69	2.47	225.07	223.13	190.32
12	VRWB-27	2.57	2.52	2.40	5.86	5.35	5.26	10.13	10.15	11.67	31.68	29.49	30.32	2.75	2.15	2.82	203.54	201.99	193.87
13	VRWB-68/NUWB-1	2.46	2.92	2.78	4.32	4.62	4.05	18.72	18.38	17.33	58.16	60.74	56.19	1.98	1.47	1.65	148.38	125.31	144.91
14	VRWB-32	2.75	3.45	3.38	5.53	6.14	6.21	21.51	22.22	22.64	99.23	102.78	109.11	1.22	1.62	1.21	170.81	149.05	148.84
15	VRWB-35	2.53	2.65	2.61	3.84	3.92	4.20	22.21	21.73	22.96	39.09	36.32	37.42	1.91	2.13	2.11	179.76	153.10	151.52
16	VRWB-36	2.60	2.67	2.40	4.28	4.67	4.23	22.79	23.47	21.55	27.58	28.89	27.10	2.38	2.35	2.34	208.65	184.82	169.44
17	LOCAL PANGTI-1	2.52	2.55	2.55	5.26	5.07	5.62	32.11	29.52	32.46	60.77	61.93	65.98	2.27	2.71	2.25	170.72	178.32	165.80
18	LOCAL DIMAPUR-1	2.72	2.85	3.02	4.58	4.21	4.34	18.04	17.00	17.72	49.83	47.10	47.68	2.91	2.26	3.06	219.65	146.89	172.49
19	VRWB-45	2.47	2.60	2.90	5.28	5.75	5.37	13.45	13.56	12.42	19.70	20.55	19.35	1.53	2.99	1.85	199.33	150.48	146.54
20	LOCAL PANGIT-2	2.58	2.27	3.03	5.00	5.33	5.71	22.44	23.17	21.83	48.54	49.63	52.17	3.96	3.21	4.30	138.96	129.36	130.86
21	LOCAL DIMAPUR-2	2.97	2.55	3.03	6.05	5.47	5.65	22.82	22.63	23.33	24.07	22.17	22.84	2.37	2.36	2.33	171.06	158.35	142.04

22	LOCAL AKUK	2.53	2.70	2.55	6.85	6.98	6.71	25.17	25.1 1	26.32	38.80	40.17	37.51	2.50	2.66	2.45	126.20	64.41	121.50
23	VRWB-50	2.68	2.48	3.12	4.37	4.42	4.25	32.86	33.0 1	29.80	40.71	41.65	43.69	3.00	2.79	3.10	137.66	137.3 2	112.85
24	VRWB-54	2.72	2.43	3.29	4.31	4.41	4.79	32.93	32.1 7	34.25	53.48	50.09	51.76	2.57	2.84	2.69	172.83	135.0 4	145.66
25	LOCAL WOKHA-1	2.98	2.82	3.15	3.81	3.32	3.29	31.18	31.7 0	33.05	44.08	45.51	42.06	2.55	3.18	3.21	178.17	125.6 8	147.53
26	VRWB-59	2.72	2.57	2.50	4.49	4.35	4.81	33.29	31.7 6	29.53	95.81	108.6 8	102.54	3.11	2.55	3.17	194.08	157.5 8	152.04
27	LOCAL DIMAPUR-3	2.63	2.74	2.73	7.31	7.82	7.60	24.02	24.7 1	26.05	25.49	25.53	26.50	1.98	2.14	2.12	169.97	136.5 6	135.98
28	VRWB-75	2.62	2.57	3.07	4.12	3.63	4.01	21.92	21.4 3	22.66	27.16	24.61	25.71	3.23	2.79	2.85	198.87	126.6 6	142.71
29	VRWB-77	2.98	2.53	2.57	4.10	4.15	4.00	17.16	17.6 1	17.88	28.23	29.51	27.40	3.13	2.78	3.41	144.60	124.3 0	133.05
30	VRBW-85	2.68	2.43	2.35	4.53	4.70	4.84	23.50	22.4 6	23.53	48.04	48.96	51.07	2.40	2.27	2.47	198.90	191.5 0	173.06
31	VRWB-88	2.50	2.32	2.30	5.23	5.73	5.17	31.59	31.1 7	33.17	39.28	41.29	38.46	1.98	2.57	2.09	196.42	153.6 8	175.50
32	LOCAL BAGHTY	2.55	2.58	2.52	3.55	3.51	4.00	29.50	28.8 2	31.44	57.77	58.84	61.56	3.23	2.84	3.42	267.19	108.1 6	126.88
33	VRWB-93	2.52	2.45	2.58	4.93	4.69	4.79	24.25	27.9 3	27.53	19.18	17.92	18.50	2.30	2.41	2.65	175.63	153.3 5	170.61
34	VRWB-100	2.90	3.19	2.70	5.01	5.14	4.64	34.39	32. 76	29.72	27.12	28.88	27.11	1.82	2.97	2.66	224.34	160.7 9	155.02
35	VRWB-104	2.45	3.03	2.52	5.46	5.27	5.92	12.40	12.7 5	13.27	29.16	29.77	31.37	2.06	1.77	1.89	152.96	147.6 5	140.04
36	LOCAL MONSENTI	2.38	2.53	2.43	5.02	4.61	4.69	30.50	30.6 6	29.15	32.78	30.74	31.42	2.40	2.55	2.56	187.72	142.3 8	153.55
37	VRWB-112	2.55	3.00	2.41	4.68	4.74	4.64	31.00	29.5 6	26.00	48.06	50.91	48.01	3.13	3.19	3.35	170.00	170.0 9	150.64
38	VRWB-115	2.48	2.75	2.40	3.95	4.12	4.74	15.69	16.4 4	16.45	43.67	44.60	46.92	1.37	1.73	1.95	141.89	126.2 3	137.62
39	VRWB-116	3.07	3.05	3.15	4.76	4.53	4.66	15.16	15.3 7	16.05	54.34	51.20	53.32	2.06	2.12	2.35	184.43	156.0 4	140.14
40	NUWB-2	2.35	2.42	2.50	4.44	4.79	4.60	23.20	23.9 7	22.67	28.82	29.89	27.58	3.02	3.20	3.20	178.68	146.5 2	145.24
	Mean	2.62	2.63	2.69	4.98	4.98	5.08	24.75	24.5 6	24.62	41.54	42.07	42.14	2.39	2.43	2.52	185.58	155.5 3	153.93
	C.V.	4.69	6.18	4.46	6.45	5.68	8.03	10.45	9.66	10.36	7.83	7.81	9.60	5.82	20.5 0	8.60	18.90	14.14	9.06
	S.E.	0.05	0.07	0.05	0.13	0.12	0.17	1.06	0.97	1.04	1.33	1.34	1.65	0.06	0.20	0.09	14.32	8.98	5.70
	C.D. 5%	0.14	0.18	0.14	0.37	0.32	0.46	2.95	2.70	2.90	3.70	3.74	4.60	0.16	0.57	0.25	39.94	25.05	15.89

Table 4.2 Continued.....

S. No.	Genotypes	Number of pods/plant			Number of seeds/pod			100 Seed Weight (g)			Seed yield/Plant (g)		
		Timely	Late	Vey late	Timely	Late	Vey late	Timely	Late	Vey late	Timely	Late	Vey late
1	LOCAL WOKHA-2	38.40	36.12	31.12	11.67	10.12	9.00	33.74	32.45	32.98	154.92	117.81	116.66
2	LOCAL SUCHONOMA	31.50	28.80	23.80	13.50	13.06	10.50	35.39	35.44	35.58	140.20	134.05	120.16
3	NUWB-4	33.30	30.84	27.35	11.33	9.41	7.33	37.60	36.51	36.66	136.94	104.54	101.67
4	LOCAL PEREN	37.59	35.22	30.23	11.33	9.62	11.33	27.62	28.09	26.27	115.27	93.68	124.60
5	LOCAL MEZDIPHEMA	34.94	32.64	27.64	13.22	12.11	11.23	32.81	32.78	31.97	135.66	130.15	135.04
6	VRWB-17	46.58	43.35	38.34	14.16	12.55	8.88	33.04	32.79	31.41	184.81	177.50	140.61
7	VRWB-20	43.44	41.90	36.90	14.46	12.90	10.23	36.36	36.38	35.21	191.21	197.87	166.43
8	VRWB-23	40.00	35.52	30.52	12.67	11.02	9.33	30.17	31.95	30.77	141.44	124.07	127.43
9	VRWB-24	44.42	42.74	37.74	11.33	10.41	7.50	28.11	28.54	27.53	143.85	130.02	107.68
10	NUWB-3	25.73	24.77	19.77	12.50	11.12	8.67	33.88	33.41	33.82	104.41	91.47	84.93
11	VRWB-26	38.65	38.40	33.40	14.17	13.60	9.84	34.86	35.51	33.88	164.43	185.96	140.01
12	VRWB-27	39.70	36.43	31.42	13.17	11.89	7.17	30.53	30.76	29.03	137.83	132.45	96.08
13	VRWB-68/NUWB-1	30.31	23.67	18.67	14.67	13.02	9.50	27.45	27.00	27.86	112.69	83.07	83.03
14	VRWB-32	34.35	23.74	22.25	14.50	14.10	9.00	26.95	27.87	26.02	125.52	91.43	82.20
15	VRWB-35	36.67	30.24	25.24	12.33	11.41	6.83	29.68	30.25	28.29	134.48	105.39	78.33
16	VRWB-36	45.00	46.58	41.58	12.67	11.08	8.50	29.34	29.40	28.70	173.93	151.12	107.03
17	LOCAL PANGTI-1	32.50	29.76	24.76	12.50	11.52	9.17	35.98	38.10	35.37	134.19	129.03	108.33
18	LOCAL DIMAPUR-1	32.80	21.51	21.99	13.83	13.39	10.33	39.13	39.13	38.09	159.99	113.84	120.36
19	VRWB-45	41.09	33.02	28.02	12.50	11.12	8.50	28.99	28.98	27.79	145.06	106.04	95.47
20	LOCAL PANGIT-2	24.42	18.56	20.01	13.33	13.02	8.50	32.53	33.93	31.58	101.75	81.92	74.21
21	LOCAL DIMAPUR-2	29.76	29.84	24.84	12.50	11.40	6.67	31.54	31.95	30.60	109.38	108.64	80.97
22	LOCAL AKUK	23.32	18.51	24.45	9.17	7.68	7.50	28.62	29.88	28.44	74.69	41.90	72.53
23	VRWB-50	37.72	30.84	25.84	10.33	9.44	7.00	24.91	25.65	24.70	98.81	75.06	69.42
24	VRWB-54	34.72	25.20	22.20	11.50	9.91	6.16	33.69	34.55	31.98	126.86	85.67	69.24
25	LOCAL WOKHA-1	40.74	28.21	23.21	11.67	10.12	7.50	25.82	24.98	24.23	118.65	71.16	74.72
26	VRWB-59	38.91	31.30	26.30	12.50	11.98	7.50	33.78	34.39	33.78	159.54	128.97	100.10
27	LOCAL DIMAPUR-3	33.66	23.36	24.18	12.83	12.98	9.50	31.29	30.46	31.16	133.95	92.19	99.65
28	VRWB-75	35.57	25.81	21.79	14.00	12.39	8.00	31.61	31.93	30.97	144.87	102.06	84.69
29	VRWB-77	31.45	22.70	17.71	12.50	11.12	8.50	28.45	27.88	27.52	111.40	70.35	79.18
30	VRWB-85	43.81	33.41	28.41	13.33	13.06	7.17	28.59	29.72	29.07	152.86	129.54	92.08
31	VRWB-88	43.50	41.28	36.28	10.17	8.15	6.17	29.43	31.27	30.17	127.59	108.28	89.03
32	LOCAL BAGHTY	27.51	20.61	21.71	11.50	10.94	7.50	28.49	27.69	27.78	91.33	62.40	81.03
33	VRWB-93	35.34	27.89	22.89	13.67	12.90	8.50	31.30	28.87	30.28	138.57	103.59	89.68
34	VRWB-100	43.01	37.63	32.63	12.50	11.62	8.83	29.40	28.28	29.94	149.86	122.34	110.87
35	VRWB-104	30.15	23.68	22.40	10.50	10.40	6.50	31.86	32.29	31.33	107.20	79.41	77.54
36	LOCAL MONSENTI	37.33	29.70	24.70	13.50	11.89	8.83	31.03	30.46	29.94	102.32	106.99	91.33

37	VRWB-112	39.55	39.18	34.18	12.17	10.58	8.00	31.27	30.74	30.18	122.06	128.43	96.65
38	VRWB-115	36.91	27.20	22.94	10.17	8.90	8.17	30.51	31.30	29.28	103.64	75.98	85.53
39	VRWB-116	40.83	38.30	33.30	11.50	10.91	7.17	28.94	29.65	28.26	123.24	125.31	90.07
40	NUWB-2	33.66	25.11	20.11	13.50	12.08	8.33	31.80	33.59	30.44	108.99	101.63	87.75
	Mean	36.22	30.84	27.02	12.48	11.37	8.37	31.16	31.37	30.47	131.11	110.03	98.31
	C.V.	10.77	8.97	7.00	8.13	11.16	7.76	8.68	7.87	8.12	13.91	16.10	12.25
	S.E.	1.59	1.13	0.77	0.41	0.52	0.27	1.10	1.01	1.01	7.45	7.23	4.92
	C.D. 5%	4.44	3.15	2.15	1.16	1.45	0.74	3.08	2.81	2.82	20.77	20.17	13.71

Pre-harvest observations

1. Plant height:

Average mean performance of plant height in table (4.2) ranged from 8.1 (VRWB-27) to 4.4 (VRWB-32) in timely sown condition, 7.93(VRWB-27) to 4.96 (VRWB-59) in late sown condition and Local Dimapur-3 (7.40) to 4.25 (VRWB-59) in very late sown condition with overall mean 5.50, 6.22 and 7.49 respectively. Among the checks, NUWB-4 (7.58), VRWB-17 (7.94), VRWB-27 (8.10), NUWB-1 (7.27), VRWB-35 (6.82), VRWB-36 (7.33), Local Dimapur-1(6.75), Local Akuk (6.98), Local Dimapur-3 (7.60), VRWB-77 (7.09) in timely sown condition followed by NUWB-4 (7.77), VRWB-17 (7.87), VRWB-27 (7.93), NUWB-1 (7.27), VRWB-36 (7.33), Local Akuk (6.77), Local Dimapur-3 (7.61), VRWB-77 (6.79) and VRWB-116 (6.86) in late sown condition and NUWB-4 (7.21), VRWB-17 (7.60), NUWB-1(6.70), VRWB-36 (6.65), Local Dimapur-3 (7.94), VRWB-77 (7.21) in very late condition were superior in Plant height. Few genotypes were superior to the best check. Among the genotypes 20 were at par significant with the best check in timely followed by 30 genotypes in the late conditions and 24 in the Very late sown conditions.

2. Days to first Flowering:

Average mean performance of days to first flowering in table (4.2) varied from days 125 days (VRWB-116) to 58 days (VRWB-17) in timely sown and 128.70 (VRWB-116) days to 56.73 days (VRWB-17) in late sown condition and 124.85 days (VRWB-116) to 58.94 (VRWB-17) in very late condition with general mean 125.33, 128.70 days and 124.85 days respectively. Among the checks, Local Medziphema was earliest in days to first flowering both in timely sown (86.67), as well as in late sown (89.82) days and in very late condition (87.61 days) condition. Nine genotypes namely VRWB-20 (62.00 days), VRWB-23 (76.00 days), VRWB-24 (85.50), VRWB-26 (81.67) VRWB-27 (61.33), Local Dimapur-2 (84.20), VRWB-93 (71.67 days), VRWB-100 (75.50 days), VRWB-112 (75.83 days) in timely sown (67.50 days) condition and

eleven genotypes namely VRWB-20 (61.51 days), VRWB-23 (78.39 days), VRWB-24 (85.50), VRWB-26 (81.67) VRWB-27 (61.33), VRWB-35 (85.35) Local Akuk (85.09), VRWB-54(88.90), Local Dimapur-2 (84.20), VRWB-93 (68.86 days), VRWB-100 (76.44 days), VRWB-112 (76.90 days) in late sown (67.50 days) and ten genotypes namely VRWB-20 (62.29 days), VRWB-23 (78.39 days), VRWB-24 (83.73), VRWB-26 (80.91) VRWB-27 (62.58), VRWB-35 (85.35) Local Akuk (85.09), VRWB-54(88.90) Local Dimapur-2 (80.90), Local Akuk (84.01), VRWB-93 (69.05 days), VRWB-100 (76.63 days), VRWB-112 (76.59 days) was significantly earlier in very late sown condition than the check Local Suchonoma. While, 25 genotypes in timely sown, 22 in late sown and 22 enotypes in very late sown condition were at par with the best check.

3. Days to 50% Flowering

Average mean performance of days to 50% flowering in table (4.2) varied from 83.36 days (VRWB-17) to 153.46 days (Local Peren) in timely sown, 80.25 days (VRWB-17) days to 151.59 days (Local Peren) in late sown condition and 83.00 days (VRWB-17) days to 153.83 days (Local Peren) in very late sown condition with general mean 125.16, 125.45 and 125.64 days respectively. Among the checks, Local Medziphema in both timely sown (121.35 days), late sown condition (118.68 days) and very late condition (122.63) was earliest check for days to 50% percent flowering. Twelve genotypes namely VRWB-20(61.51), VRWB-23(78.29), VRWB-24 (86.31), VRWB—27(89.76), Local Dimapur-2(104.64), Local Akuk(117.01), VRWB-54(115.4), Local Baghty(1 m20.43), VRWB-75(117.28), VRWB-85(118.56), VRWB-93(95.45), VRWB-100(103.16), VRWB -112 (110.04), VRWB-115 (114.68) in timely sown and eleven genotypes namely VRWB-20(92.00), VRWB-23(113.95), VRWB-24(108.38), VRWB—27(90.41), Local Dimapur-2(104.65), Local Akuk(111.19), VRWB-54(113.78), VRWB-75(110.21), VRWB-85(118.80), VRWB-93(98.07), VRWB-100(103.89), VRWB-112(111.36), VRWB-

115(112.83) in late sown condition and VRWB-20 (94.16), VRWB-23(120.0),VRWB-24(107.41), VRWB—27(87.74), Local Di,apur-2(108.11), Local Akuk(116.05), VRWB-50 (121.50), Local Baghty (118.50), VRWB-54(113.40), VRWB-75(113.82), VRWB-85(118.00), VRWB-93(95.00) , VRWB-100(103.05) , VRWB-112(108.00) , VRWB-115(117.71) in Very-late sown condition were earlier than best check Local Medziphema. BRCHT-13 (84.75 days) in timely sown and JG-62 (73.50 days) in late sown condition showed similar performance to the best check. Among the rest of the genotypes, 19 genotypes showed at par performance with the best check Local Medziphema in their respective environment.

4. Days to Pod initiation

The mean performance of days to pod initiation in table (4.2) ranged from 62.83 (VRWB-17) to 127.83 (VRWB-116) in timely sown and 54.18 (VRWB-17) to 126.72 (Local Peren) in late sown condition with and 71.33(VRWB-20) to 126.72 (VRWB-116) in Very-late sown condition with general mean 98.96, 99.92 and 99.25 respectively. Among the checks, Local Medziphema in both timely sown (91.67), late sown (95.33) condition and Very-late sown (90.89) was the best check. 11 genotypes namely VRWB-17(62.83), VRWB-20(67.00), VRWB-23(80.67), VRWB-24(89.50), VRWB-26(88.33), VRWB-27(68.67), VRWB-35(91.18), Local Akuk(88.79), VRWB-54(91.37), VRWB-93(74.67),VRWB-100(79.67),VRWB-112(79.50), VRWB-115(90.50) in Timely sown conditions and also 14 genotypes namely VRWB-17(54.18), VRWB-20(61.62), VRWB-23(88.20), VRWB-24(86.07), VRWB-27(62.93), VRWB-35(91.18), Local Dimapur-2(82.66), Local Akuk(88.79), VRWB-54(91.37),VRWB-77(90.66),VRWB-93(68.38),VRWB-100(81.88),VRWB-112(79.64), VRWB-115(86.80) in late sowing conditions and 11 genotypes namely VRWB-17(72.67), VRWB-20(71.33), VRWB-23(76.67), VRWB-24(85.89), VRWB-26(89.00), VRWB-27(74.33), Local Dimapur-2(84.56), VRWB-54(87.11), VRWB-93(74.67), VRWB-100(81.67), VRWB-112(81.67)

in very-late conditions were superior than the best check Local Medziphema. Among the rest of the genotypes, six genotypes in timely sown, three genotypes in late sown condition and six genotypes in Very-late sown condition showed at par performance with the best check Local Medziphema. Out of forty, 27 genotypes under timely, 15 in the Late sown condition and 20 genotypes under Very late sown condition had significantly superior value than the best check Local Medziphema.

5. Days to Maturity

The mean performance of days to maturity in table (4.2) ranged from 142.17 (VRWB-27) to 214.67 (NUWB-3) in timely sown and 143.67 (VRWB-17) to 214.83 (Local Peren) in late sown condition with and 137.11 (VRWB-27) to 215.61 (NUWB-3) in late sown condition general mean 182.13, 181.63 and 179.95 respectively. Among the checks, Local Suchonoma in both timely sown (202.67), late sown (200.83) condition and Very-late sown (194.28) was the best check. genotypes in Timely sown conditions and also 35 in late sowing conditions and 34 in very-late conditions were superior than the best check Local Medziphema. Among the rest of the genotypes, five genotypes in timely sown, five genotypes in late sown condition and six genotypes in Very-late sown condition showed at par performance with the best check Local Suchonoma. Out of forty, 27 genotypes under timely, 15 in the Late sown condition and 20 genotypes under Very late sown condition had significantly superior value than the best check Local Medziphema. VRWB-17 (145.17), VRWB-20 (147.83), VRWB-23 (171.83), VRWB-24 (155.00), Among the genotypes VRWB-26 (194.17), VRWB-27 (142.17), NUWB-1 (198.00), VRWB-32 (183.33), VRWB-35 (194.67), VRWB-36 (186.33), Local Dimapur-1 (198.00), VRWB-45 (195.50), LOCAL PANGIT-2 (199.50), Local Dimapur-2 (171.67), Local Akuk (174.17), VRWB-50 (187.50), VRWB-54 (162.33), Local Wokha-1 (182.50), VRWB-59 (184.83), Local Dimapur-3 (192.67), VRWB-75 (191.33), VRWB-77 (168.67), VRBW-85 (175.50), VRWB-88 (181.50), Local

Baghty (167.67), VRWB-93 (151.83), VRWB-100 (153.00), VRWB-104 (188.83), Local Mongsenyimti (182.00), VRWB-112 (155.67), VRWB-115 (166.33), VRWB-116 (194.83), NUWB-2 (185.50) in timely sown conditions followed by 35 genotypes in Late sown conditions namely Local Wokha-2 (200.67), VRWB-17 (143.67), VRWB-20 (146.50), VRWB-23 (173.83), VRWB-24 (153.17), VRWB-26 (191.00), VRWB-27 (145.63), NUWB-1 (197.50), VRWB-32 (182.67), VRWB-35 (183.67), VRWB-36 (188.12), Local Dimapur-1 (196.83), VRWB-45 (192.00), Local Pangit-2 (198.33), Local Dimapur-2 (168.67), Local Akuk (177.50), VRWB-50 (187.33), VRWB-54 (165.33), Local Wokha-1 (186.00), VRWB-59 (185.67), Local Dimapur-3 (197.17), VRWB-75 (189.17), VRWB-77 (173.00), VRWB-85 (170.33), VRWB-88 (181.83), Local Baghty (165.17), VRWB-93 (149.17), VRWB-100 (154.50), VRWB-104 (191.50), Local Mongsenyimti (177.33), VRWB-112 (158.50), VRWB-115 (162.33), VRWB-116 (197.17), NUWB-2 (184.83) and 34 genotypes in Very late sown conditions namely Local Wokha-2 (192.67), VRWB-17 (153.17), VRWB-20 (142.22), VRWB-23 (176.94), VRWB-24 (154.50), VRWB-26 (192.06), VRWB-27 (137.11), NUWB-1 (195.50), VRWB-32 (182.00), VRWB-35 (181.44), VRWB-36 (189.89), Local Dimapur-1 (194.89), VRWB-45 (189.56), Local Dimapur-2 (166.17), Local Akuk (174.22), VRWB-50 (179.67), VRWB-54 (160.61), Local Wokha-1 (184.78), VRWB-59 (189.06), Local Dimapur-3 (194.50), VRWB-75 (186.39), VRWB-77 (168.39), VRWB-85 (176.06), VRWB-88 (177.39), Local Baghty (165.39), VRWB-93 (145.83), VRWB-100 (157.44), VRWB-104 (173.56), Local Mongsenyimti (181.89), VRWB-112 (155.33), VRWB-115 (164.72), VRWB-116 (197.56), NUWB-2 (183.11) performed better than the best check variety Local Suchonoma. Out of forty genotypes, 20 in the timely, 18 in the late and 23 in the Very late sown conditions were at par with the local check.

6. Pod Length (cm)

The mean performance of pod length ranges 27.71 Local Dimapur-3) to 13.61 (Local Akuk) in timely sown and 22.01 (Local Dimapur-3) to 12.10 (VRWB-88) in late sown condition with and 22.65 Local Dimapur-3) to 13.19 (VRWB-59) in Very-late sown condition with general mean 16.29, 16.36 and 16.60 respectively. Among the checks, Local Medziphema in both timely sown (20.60), late sown (21.46) condition and Very-late sown (22.08) was the best check. 1 genotype namely 27.71 (Local Dimapur-3) in Timely sown conditions and also 1 genotype namely 22.01 (Local Dimapur-3) in late sowing conditions and 1 genotype namely Local Dimapur-3 (22.65), in very-late conditions were superior than the best check Local Suchonoma. Among the rest of the genotypes, 1 Local Dimapur-3 in genotypes in timely sown late sown condition and in Very-late sown condition showed at par performance with the best check Local Medziphema.

7. Pod Width (cm)

The mean performance of pod width (cm) in table (4.2) ranged from 3.07 (VRWB-116) to NUWB-1 (2.35) in timely sown and 3.45 (VRWB-32) to 2.27 (Local Pangti-2) in late sown condition with and 3.38 (VRWB-32) to 2.07 (VRWB-112) in Very-late sown condition with general mean 2.60, 2.63 and 2.68 respectively. Among the checks, Local Suchonoma in timely sown condition (2.47) and Local Medziphema in both late sown (2.57) and very late sown (2.57) conditions was the best check. 22 genotypes namely NUWB-4 (2.57), Local Peren (2.58, VRWB-17 (2.58) VRWB-20(2.92), VRWB-23(2.43), VRWB-24(2.98), VRWB-26(2.57), VRWB-27(2.57), VRWB-32(2.75), VRWB-35(2.53), VRWB-36(2.60), Local Pangti-1(2.52) Local Dimapur-1(2.72), VRWB-45(2.47), Local Pangti-2(2.58), Local Dimapur-2(2.97), Local Akuk(2.53), VRWB-50(2.68), VRWB-54 (2.72), Local Wokha-1 (2.98), VRWB-59 (2.72), Local Dimapur-3 (2.63), VRWB-75 (2.62), VRWB-77(2.98), VRWB-88 (2.50), Local Baghty (2.55), VRWB-93(2.52), VRWB-100 (2.90),

VRWB-104 (2.45), VRWB-112 (2.55), VRWB-115 (2.48), VRWB-116 (3.07) were found to be superior than the local best check Local Suchonoma in timely sown condition. 15 genotypes namely VRWB-23 (2.63), VRWB-24(2.77), NUWB-3 (2.58), NUWB-1 (2.92), VRWB-32 (3.45), VRWB-35(2.65), VRWB-36 (2.67), Local Dimapur-1 (2.85), VRWB-45 (2.60), Local Akuk (2.70), Local Wokha-1 (2.82), Local Dimapur-3 (2.73), VRWB-100 (3.18), VRWB-112 (3.00) VRWB-115 (2.75), VRWB-116 (3.05) in late condition. 21 genotype namely Local Wokha-2 (2.58), Local Peren (2.65), VRWB-17 (2.70), VRWB-20 (3.12), VRWB-24 (2.72), VRWB-26 (2.65), NUWB-1 (2.78), VRWB-32 (3.38), VRWB-35, (2.61), Local Dimapur-1 (3.02), VRWB-45 (2.90), Local Pangti-2 (3.03), Local Dimapur-2 (3.03), VRWB-50 (3.12), VRWB-54 (3.28), Local Wokha-1 (3.15), Local Dimapur-3 (2.73) VRWB-75 (3.07), VRWB-93 (2.58), VRWB-100 (2.70), VRWB-116 (3.15) in Very-Late conditions were superior than the best check Local Medziphema. Among the rest of the genotypes, 31 genotypes in timely sown, 25 genotypes in late sown condition and 21 genotypes in Very-late sown condition showed at par performance with the best check Local Medziphema.

8. Pod yield per plant

The mean performance for pod yield per plant in table (4.2) ranged from 267.18 (Local Baghty) to 126.19 (Local Akuk) in timely sown 240.22 (VRWB-20) to 64.40 (Local akuk) in late sown condition and 200.64 (VRWB-20) to 112.85 (Local Baghty) in Very-late sown condition with general mean 185.58, 155.53 and 153.93 respectively. Among the checks, Local Medziphema in timely sown (210.14), In late sown (229.64) condition and in Very-late (221.39). Local Medziphema in the timely (210.14), Late (229.64) and Very late Conditions (221.39) was found to be the best check in the all conditions. Among the genotypes VRWB-20 (243.64), VRWB-17 (260.52), VRWB-26 (225.07) and Local Dimapur-3 (219.97), Local baghty (267.19) and VRWB-100 (224.34) in the Timely sown conditions followed by Local Wokha 2 (181.07), VRWB-17

(260.52), VRWB-26 (223.13), VRWB-27 (201.99), VRWB-36(184.82) and VRWB-20 (240.23) in Late conditions and Local Wokha 2 (185.11), VRWB-17 (179.16), VRWB-26 (190.32), VRWB-27 (193.87), VRWB-36 (169.44), Local Pangti-1 (165.80), VRWB-88 (175.50), VRWB-85(173.06), VRWB-93 (170.61) and VRWB-20 (200.61) were performed better than the Local best check. Among the rest of the genotypes, 6 genotypes in timely sown and 6 genotypes in late sown condition and 11 genotypes in the Very late condition showed at par performance with the best check Local Medziphema.

9. Number of Pods Per plant

The mean performance for number of pods per plant in table (4.2) ranged from 46.58 (VRWB-17) to 23.31 (local Akuk) in timely sown 46.57 (VRWB-17) to 18.50 (local Akuk) in late sown condition and 41.57 (VRWB-17) to 17.07 (local Akuk) in Very-late sown condition with general mean 36.22, 30.84 and 27.02 respectively. Among the checks, Local Medziphema in timely sown (34.04), late sown (32.61) condition and in Very-late (27.64) was the best check. 21 genotypes namely Local Wokha-2(38.40), Local Peren (37.59) VRWB-17(46.58), VRWB-20(43.44), VRWB-23 (40.00), VRWB-24 (41.84), VRWB-26 (38.65), VRWB-27 (39.70), VRWB-35 (36.67) VRWB-36 (45.00), VRWB-45 (41.00), Local wokha-1 (40.74), VRWB-59 (38.91), VRWB-85 (43.50), VRWB-88 (43.50), VRWB-100 (43.01), VRWB-112 (39.55) (VRWB-116(40.83) in timely condition. 14 genotype namely Local Wokha-2 (36.12), Local Peren (35.22), VRWB-17(43.35), VRWB-20 (41.91), VRWB-23(35.52), VRWB-24(42.74), VRWB-26(38.40), VRWB-27(36.43), VRWB-36 (46.50), VRWB-88 (41.28), VRWB-100 (37.63), VRWB-112 (39.18), VRWB-116 (38.30) for late condition. 24 genotypes namely Local Wokha-2 (31.12), Local Peren (30.23) VRWB-17 (38.34), VRWB-20(36.90), VRWB-23(30.52), VRWB-24(37.74), VRWB-26(33.40), VRWB-27(31.42), VRWB-36 (41.58), VRWB-88 (36.28), VRWB-112(34.18), VVRWB-116(33.30) for very late conditions were superior than the best check Local Medziphema. Among the rest

of the genotypes, twenty-one genotypes in timely sown, thirteen genotypes in late sown condition showed and twelve genotypes in Very-late sown condition at par performance with the best check Local Medziphema. Among the genotypes, 26 showed at par performance with the best check Local Medziphema in the timely sown followed by 29 in the Late sown and 16 in the Very late sown Conditions in their respective environment.

Post harvest Observations

10. Seed yield /plant (g)

The mean performance of seed yield /plant (g) in table (4.2) ranged from 191.20 (VRWB-20) to Local Akuk (74.68) in timely sown and 197.98 (VRWB-20) to 41.90 (Local Akuk) in late sown condition with and 152.14 (VRWB-20) to 64.37 (Local Akuk) in Very-late sown condition with general mean 98.43, 99.14 and 101.41 respectively. Among the checks, Local Suchonoma in timely sown condition (105.68), late sown (104.83) and very late sown (104.61) conditions was the best check. In the Timely condition 12 genotypes namely Local Wokha-2 (154.92), VRWB-17 (184.81), VRWB-20 (191.21), VRWB-23 (141.44), VRWB-24 (143.85), VRWB-26 (164.43), VRWB-36 (173.93), Local dimapur-1 (159.99), VRWB-45 (145.06), VRWB-59 (159.54), VRWB-75 (144.87) and VRWB-100 (149.86), performed better than the local check followed by 4 genotypes in the Late condition namely VRWB-17 (177.50), VRWB-20 (197.87), VRWB-26 (185.96), VRWB-27 (132.45) and VRWB-36 (151.12) and in the Very Late conditions 3 genotypes namely VRWB-17 (140.61), VRWB-20 (166.43) and VRWB-26 (140.01) were found to be the better performer. Out of the forty, 12 genotypes in timely 4 in Late and 3 in the Very Late conditions were at par with the best local check Local Suchonoma.

11. Tuber Weight (g)

The mean performance of tuber weight (g) in table (4.2) ranged from 99.23 (VRWB-32) to VRWB-93 (19.18) in timely sown and 102.78 (VRWB-32) to 17.92 (VRWB-93) in late sown condition with and 109.11 (VRWB-32)

to 18.50 (VRWB-93) in Very-late sown condition with general mean 41.54, 42.07 and 42.14 respectively. Among the checks, Local Suchonoma in timely sown condition (48.64), in late sown (48.01) and very late sown (50.18) conditions was the best check. 14 genotypes namely NUWB-4 (46.75), Local Peren (48.86), VRWB-23 (47.23), NUWB-1 (58.16), VRWB-32 (99.23), Local Pangti-1 (60.77), Local Dimapur-1(49.83), Local Pangti-2 (48.54) VRWB-54 (53.48), VRWB-59 (95.81), VRWB-85 (48.04), Local Baghty (57.77), VRWB-112 (48.06), VRWB-116 (54.33), followed by 12 genotypes in the late condition Local Peren (50.83), VRWB-23 (48.10), NUWB-1 (60.74), VRWB-32 (102.78), Local Pangti-1 (61.93), Local Pangti-2(49.63), VRWB-54 (50.09), VRWB-59 (108.68), VRWB-85 (48.96), Local Baghty (58.84), VRWB-112 (50.91), VRWB-116 (51.21) and 9 genotypes in the very late condition namely VRWB-23(50.59), NUWB-1(56.19), VRWB-32 (109.11), Local Baghty (52.17), VRWB-54 (51.76), VRWB-59(102.54), VRWB-85(51.07), Local Baghty (51.07), VRWB-116 (53.32) were found to be performed better than the local check. Out of the forty, 14 genotypes in timely, 9 in Late and 7 in the Very Late conditions were at par with the best local check Local Suchonoma.

12. Tuber Diameter (cm)

The mean performance of tuber diameter (cm) in table (4.2) ranged from 3.96 (Local Pangti-2) to (VRWB-32) (1.22) in timely sown and 3.20 (NUWB-2) to 1.46 (NUWB-1) in late sown condition with and 4.30 (Local Pangti-2) to 1.21 (VRWB-32) in Very-late sown condition with general mean 2.39, 2.44 and 2.52 respectively. Among the checks, Local Suchonoma performed in all three conditions *i.e.* timely sown condition (2.35), in late sown (2.35) and very late sown (2.53) conditions was the best check. 18 genotypes in Timely conditions namely Local Wokha-2 (3.05), VRWB-24 (2.61), VRWB-27(2.69), Local Dimapur-1 (2.26), Local Dimapur-2 (2.36), Local Akuk (2.66), VRWB-50 (2.79), VRWB 54 (2.48), Local Wokha-1 (3.18), VRWB_59 (2.55), VRWB-75 (2.79) VRWB_77 (2.78), VRWB-88 (2.57), Local Baghty (3.25), Local

Mongsenyimti (2.55), VRWB-112 (3.13), followed by 17 genotypes in Late conditions namely Local Wokha-2 (2.85), VRWB-24 (3.55), VRWB-27(2.82), Local dimapur-1 (3.06), Local Pangti-2 (4.30), Local Akuk (2.45), VRWB-50 (3.10), Local wokha-1(3.21), VRWB-59(3.17), VRWB-75 (2.85), VRWB-77 (3.41), VRWB-85 (2.47), Local Baghty (3.42), VRWB-93 (2.65), VRWB-100 (2.66), Local Mongsenyimti (2.56), VRWB-`112 (3.35), NUWB-2(3.20) and lastly very late condition 16 genotypes namely Local Wokha-2 (2.85), VRWB-24 (3.55), VRWB27 (2.82), Local Dimapur-1 (3.03), Local Pangti-2 (4.30), VRWB-50 (3.10), VRWB-54 (2.69), Local Wokha-1 (3.21), VRWB-59, VRWB-77 (3.48), Local Baghty (3.42), VRWB-93 (2.65), VRWB-100 (2.66), Local Mongsenyimti (2.56), VRWB-112(3.36), NUWB-2 (3.20) performed better than the best Local check. Out of the forty, 18 genotypes in timely, 23 in Late and 16 in the Very Late conditions were at par with the best local check Local Suchonoma.

13. Number of seed per pod

The mean performance of **Number of seed per pod** in table (4.2) ranged from (14.67) NUWB-1 to Local Akuk (9.17) in timely sown and (14.10) VRWB-32 to 7.68 (Local Akuk) in late sown condition with and (11.33)Local Peren to 6.16 (Local Akuk) in Very-late sown condition with general mean 12.48, 11.37 and 8.37 respectively. In timely sown conditions 6 genotype namely VRWB-17 (14.16), VRWB-20 (14.46), VRWB-26 (14.17), NUWB-1 (14.67), VRWB-32 (14.50), and VRWB-75 (14.00) followed by 3 genotypes in the late conditions namely VRWB-26 (13.60), VRWB-32 (14.10) and Local Dimapur-1 (13.39) in the Very- late conditions namely Local peren (11.33) were found to be better than the best local check variety. Out of the forty, 6 genotypes in timely, 3 in Late and 1 in the Very Late conditions were at par with the best local check Local Medziphema.

14. 100 Seed Weight (g)

The mean performance of 100 seed weight(g) in table (4.2) ranged from 39.12 (Local Dimapur-1) to 24.91 (VRWB-50) in timely sown and 39.12 (Local Dimapur-1) to 24.97 (Local Wokha-1) in late sown condition with and 38.06 (Local Dimapur-1) to 24.23 (Local wokha-1) in Very-late sown condition with general mean 31.16, 31.37 and 30.47 respectively. Among the checks, Local Suchonoma in timely sown condition (33.50), in late sown (35.44) and very late sown (35.58) conditions was the best check. 4 genotypes namely NUWB-4 (37.60), VRWB-20 (36.36), Local Pangti-1 (35.98) and Local Dimapur-1 (39.13) in timely sown condition followed by 5 genotypes in late sown condition NUWB-4 (36.51), VRWB-20 (36.38), VRWB-26 (35.51), Local Pangti-1 (38.10) and Local Dimapur-1 (39.13) and 2 genotypes in Very late NUWB-4 (36.66) and Local Dimapur-1 (38.09). Out of the forty, 5 genotypes in timely, 4 in Late and 2 in the Very Late conditions were at par with the best local check Local Suchonoma.

15. Dry Pod Weight (g)

The mean performance of dry pod weight (g) in table (4.2) ranged from 7.30 (Local Dimapur-3) to Local Baghty (3.55) in timely sown and 6.98 (Local Dimapur-3) to 3.32 (Local wokha-1) in late sown condition with and 7.60 (Local Dimapur-3) to 3.29 (Local wokha-1) in Very-late sown condition with general mean 4.98, 4.98 and 5.08 respectively. Among the checks, Local Medziphema in timely sown condition (6.20) in both late sown (6.36) and very late sown (6.99) conditions was the best check. 3 genotypes in timely condition namely VRWB-17 (6.82), Local Akuk (6.85) and Local Dimapur-3 (7.30) followed by 2 genotypes in late condition namely Local Akuk (6.98) and Local Dimapur-3 (7.82), and one genotype in Very-Late condition Local Dimaour-3 (7.60) were found to be performed better than the best local check variety. Out of the forty, 8 genotypes in timely, 5 in Late and 5 in the Very Late conditions were at par with the best local check Local Medziphema.

16.Tuber Length (cm)

The mean performance of tuber length (cm) in table (4.2) ranged from (39.52) NUWB-3 to 10.13 (VRWB-27) in timely sown and (39.30) NUWB-3 to 10.15 (VRWB-27) in late sown condition with and (39.45) NUWB-3 to 11.67 (VRWB-27) in Very-late sown condition with general mean 24.75, 24.56 and 24.62 respectively. Among the checks, Local Medziphema in in timely sown condition (34.06), in late sown (31.39) and very late sown (32.26) conditions was the best check. In the timely sown conditions 7 genotypes namely VRWB-23 (34.57), NUWB-3(39.52), Local Pangti-2 (32.11), VRWB-50 (32.86), VRWB-54 (32.93), VRWB-59(33.29), VRWB-100 (34.39) followed by 7 genotypes in the late sown conditions NUWB-3 (39.30), VRWB-23(34.67), VRWB-50 (33.01), VRWB-54 (32.17), Local Wokha-1 (31.70), VRWB-59 (31.76), VRWB-100 (32.76) and 6 genotypes int the Very Late sown conditions namely NUWB-3 (36.54), VRWB-23(34.98), Local Pangti-1 (34.25), VRWB-54 (34.25), Local Wokha-1 (33.05), VRWB-88(33.17) were found to be better than the best local check variety. Out of the forty, 5 genotypes in timely, 14 in Late and 15 in the Very Late conditions were at par with the best local check Local Medziphema.

4.4.Estimates of component of variance, Coefficient of variation, Heritability and Genetic advance

4.4.1. Variance:

Estimates of phenotypic variance (σ^2p) and genotypic variance (σ^2g) were computed for different traits and are presented in Table 4.3. The highest value of σ^2p was observed for pod yield per plant (2099.30) in timely condition across the environment followed by seed yield per plant (1304.06) and days to maturity (548.61), days to 50% flowering (406.16) and days to first flowering (374.99) in late sown condition followed by tuber weight (370.48) in very late condition. The lowest value was recorded for dry pod weight in all conditions

lowest value was (0.05) in timely condition. The highest value of σ^2g was observed for pod yield per plant (1048.63) across the environment followed by seed yield per plant (990.31), days to pod initiation (328.54) and number of pods per plant (51.39) in late condition followed by days to maturity (380.51), and tuber length (48.77) in timely sown condition and days to 50 % flowering (311.65) and tuber weight (354.13) in very late condition. The lowest value was recorded for pod width (0.04). Under timely sown condition, Close perusal of table 4.3 revealed that for days to first flowering, days to 50% flowering, days to maturity, days to pod initiation and tuber weight there was a little difference between genotypic and phenotypic variance, in all timely, late and very-late conditions. Environmental variance was also negligible indicating very less influence of environmental factors on these traits. For other traits, proportion of environmental variance was found high which revealed higher environmental influences on these traits. Minimum difference between the respective estimates of σ^2p and σ^2g along with higher value of σ^2g was observed for all the traits in all three conditions which suggested that the variability present among the genotypes for those traits were mainly due to genotype with minimum influence of environment and hence heritable.

4.4.2. Genotypic and Phenotypic Coefficient of Variation

The estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for all the traits are presented in Table 4.3. The estimates of phenotypic coefficient of variation (PCV) in general, were higher than the estimates of genotypic coefficient of variation (GCV) for all the traits,

which suggested that the apparent variation is not only due to the genotypes but also due to the influence of environment. A wide range of GCV was observed ranging from 7.11 (pod width) to 40.88 (tuber weight) in timely sown condition followed by in late condition from 9.25 (pod width) to 44.07 (tuber weight) lastly in very late sown condition 9.82 (100 seed weight) to 44.66 (tuber weight). The PCV varied from 8.25 (pod width) to 41.57 (tuber weight) in timely sown condition followed by late condition from 11.13 (pod width) to 44.76 (tuber weight) and in very late condition from 11.74 (pod width) to 45.68 (tuber weight). Higher magnitudes of PCV were recorded for tuber weight (41.57), tuber length (30.09), tuber diameter (26.76), pod yield per plant (24.69), seed yield per plant (23.19), and days to first flowering (20.03) in timely sown condition. Under late sown condition, high values of PCV were recorded for tuber weight (44.76), tuber length (28.68), tuber diameter (26.63), pod yield per plant (25.17), seed yield per plant (32.82), and days to first flowering (20.39) lastly under very late sown condition, high values of PCV were recorded for tuber weight (45.68), tuber length (28.31), tuber diameter (26.60) and seed yield per plant (23.37). The maximum GCV was noticed for tuber weight (40.83), tuber diameter (26.12) and tuber length (28.21) in the timely conditions. In late sown condition, higher GCV was noticed for tuber weight (44.07), pod yield per plant (20.82), tuber length (27.00), seed yield per plant (28.60) and number of pods per plant (23.25) and lastly in very-late sown condition, higher GCV was noticed for tuber weight (44.66), tuber length (26.34), seed yield per plant (22.21) and number of pods per plant (22.08). Moderate estimate of PCV was observed for plant height (18.47), days to 50% flowering (15.82), days to pod initiation, dry pod weight (18.81), number of pods per plant (18.70), number of seed per pod (12.94), pod length (15.27) and 100 seed weight (12.93) under timely sown condition followed by in late condition for plant height (15.78), days to 50% flowering (16.07), days to pod initiation (19.38), dry pod weight (19.40), number of seed per pod (16.73), pod length (16.41) and 100 seed weight

(12.68) for and under very late sown condition plant height (16.43), days to 50% flowering (18.58), days to pod initiation (18.09), dry pod weight (19.57), number of seed per pod (17.15), pod length (17.22) and 100 seed weight (12.74) across the environment. Moderate estimate of GCV was observed for plant height (16.39), Days to first flowering (17.65), days to 50% flowering (13.63), days to pod initiation (16.89), dry pod weight (17.67), number of pod per plant (15.28), pod length (11.46) and seed yield per plant (18.55) also under late sown condition moderate GCV was found in plant height (15.51), Days to first flowering (17.73), days to 50% flowering (14.05), days to pod initiation (17.36), dry pod weight (18.55), number of seeds per pod (12.46), tuber diameter (17.00) and pod length (13.01) also for the very late condition plant height (13.02), Days to first flowering (18.17), days to 50% flowering (14.05), days to pod initiation (17.63), dry pod weight (17.84), number of seeds per pod (15.29) and pod length (14.29) across the environment. All remaining traits show low estimates of phenotypic and genotypic coefficient of variation.

4.4.3. Heritability and Genetic Advance as percent of mean

As per data (Table 4.3) it is evident that the heritability (broad sense) estimated for the sixteen quantitative traits was ranged from 55% (100 seed weight) to tuber weight (97%) in timely sown condition and tuber width (41%) to tuber weight (97%) in late sown condition followed by tuber weight (96%) and 100 seed weight (59%) in very late condition. Higher heritability was observed for the traits like plant height (79%), days to first flowering (78%), days to 50% flowering (74%), days to pod initiation (87 %), days to maturity (86%), pod width (70%), dry pod weight (88%), tuber length (88%) tuber weight (97%), tuber diameter (95%), number of pods per plant (67%) and seed yield per plant (64%) in timely sown condition while plant height (68%), days to first flowering (79 %), days to 50% flowering (76 %), days to pod initiation (88%), pod length (63%), days to maturity (64%), pod width (69%), dry pod weight (91%), tuber length (89%) tuber weight (97%), pod yield per plant (68%), number of pods per plant (87%), 100 seed weight (62%) and seed yield per plant

(76%) showed high heritability in late sown condition and lastly on the very late sown condition the characters plant height (89%), days to first flowering (91%), days to 50% flowering (87 %), days to pod initiation (92%), pod length (69%), days to maturity (82%), pod width (86%), dry pod weight (83%), tuber length (87%) tuber weight (96%), pod yield per plant (65%), number of pods per plant (91%), number of seeds per pod (80%) and seed yield per plant (77%) followed by pod length (56%), pod yield per plant (41%), and 100 seed weight (55%) under timely condition tuber diameter (41%) and number of seeds per pod (56%) exhibited higher heritability under late condition followed by 100 seed weight (59%) showed high heritability across the very late condition environment. Thus, covering all traits under all the environments there was no such traits which was poorly heritable.

Genetic advance as percent of mean (Table 4.3) for the traits under study revealed that it was ranged from tuber weight (82.61) to pod width (12.22) in timely sown condition while days to tuber weight (89.39) to pod width (15.85) in late sown condition while in very late condition range varied from tuber weight (89.95) to 100 seed weight (15.58). High genetic advance as percent of mean was also observed for plant height (30.03), days to first flowering(32.04), days to 50% flowering(24.20), days to pod initiation (32.42), days to maturity (20.49), dry pod weight (34.20), pod yield per plant (21.05), number of pods per plant (25.72), tuber weight (82.61), tuber length (54.50) and seed yield per plant (30.57) in timely condition, in late plant height (22.12), days to first flowering(33.36), days to 50% flowering (25.08), days to pod initiation (34.54), pod length (21.23), dry pod weight (36.54), pod yield per plant (35.48), number of pods per plant (44.68), tuber length (54.50) and seed yield per plant (51.34), tuber weight (89.39) and tuber diameter (22.35) displayed high genetic advance as per cent of mean and very late condition tuber weight (89.95) and tuber diameter (49.08), seed yield per plant (40.06) moderate genetic advance as percent of mean was observed in in timely condition followed by tuber length (52.37) and seed yield per plant (51.34) in late condition followed by tuber

length (50.50), seed yield per plant (40.06), plant height (30.16), days to first flowering (33.36), days to 50% flowering (26.92), days to pod initiation (34.32), pod length (24.41), dry pod weight (33.52), tuber length (50.50), tuber weight (89.95), pod yield per plant (20.43), number of pods per plant (43.36) number of seeds per pod (28.09) and tuber diameter (49.08) at very late condition.

Moderate genetic advance as percent of mean was observed for pod length (17.71), pod width (12.22), number of seed per plant (16.13) and 100 seed weight (14.62) in timely condition followed by 100 seed weight (16.06), number of seeds per pod (19.11), pod width (15.85) and days to maturity (17.04) exhibited moderate genetic advance as percent of mean under late sown environment followed by days to maturity (19.57) and 100 seed weight (15.58) showed moderate magnitude of genetic advance as percent of mean under very late conditions.

Table 4.3: Estimates of genetic parameters for sixteen quantitative characters in forty genotypes of winged bean under Timely, Late and very late sown condition

Cha ra- cters	Range						Genotypic (σ^2_g)			GCV			Phenotypic (σ^2_p)			PCV			h ² (%)			GA as % of Mean		
	Lowest			Highest																				
	Tim ely	Lat e	Very late	Tim ely	Lat e	Very late	Tim ely	Late	Very late	Tim ely	Lat e	Very late	Time ly	Late	Very late	Tim ely	Lat e	Very late	Tim ely	Lat e	Very late	Tim ely	Lat e	Very late
PH	3.97	4.96	4.20	7.28	7.93	7.29	0.81	0.66	0.79	16.3 9	13. 02	15.51	1.03	0.97	0.88	18.4 3	15. 78	16.43	79.0 0	68. 00	89.00	30.0 3	22. 13	30.16
DFE	58.0 0	56.7 3	58.94	125. 33	128. 70	124.8 5	279. 73	297.4 6	280.9 9	17.6 5	18. 17	17.73	360.2 0	374.4 9	308.6 3	20.0 3	20. 39	18.58	78.0 0	79. 00	91.00	32.0 4	33. 36	34.84
DFP F	83.3 7	80.2 5	83.00	153. 46	153. 01	153.8 3	291. 09	307.8 6	311.6 5	13.6 3	13. 99	14.05	391.8 0	406.1 6	360.2 3	15.8 2	16. 07	15.11	74.0 0	76. 00	87.00	24.2 0	25. 08	26.92
DPI	62.8 3	54.1 8	63.80	129. 67	126. 72	130.3 9	279. 33	328.5 4	296.8 0	16.8 9	18. 14	17.36	321.7 1	374.9 9	322.1 5	18.1 2	19. 38	18.09	87.0 0	88. 00	92.00	32.4 2	34. 98	34.32
DM	142. 17	143. 67	137.1 1	214. 67	214. 83	215.6 1	380. 51	351.8 8	358.4 5	10.7 1	10. 33	10.52	441.1 8	548.6 1	439.5 4	11.5 3	12. 89	11.65	86.0 0	64. 00	82.00	20.4 9	17. 04	19.57
PL	13.6 1	13.2 3	13.19	21.7 2	22.0 1	22.65	3.49	4.56	5.63	11.4 6	13. 01	14.29	6.19	7.26	8.17	15.2 7	16. 41	17.22	56.0 0	63. 00	69.00	17.7 2	21. 23	24.41
PW	2.35	2.27	2.30	3.07	3.45	3.38	0.04	0.06	0.09	7.11	9.2 5	10.85	0.05	0.09	0.10	8.52	11. 13	11.74	70.0 0	69. 00	86.00	12.2 2	15. 85	20.68
DP W	3.55	3.32	3.29	7.31	7.82	7.60	0.78	0.86	0.82	17.6 7	18. 55	17.84	0.88	0.94	0.99	18.8 1	19. 40	19.57	88.0 0	91. 00	83.00	34.2 0	36. 54	33.52
TL	10.1 3	10.1 5	11.67	39.5 2	39.3 0	36.45	48.7 7	43.96	42.06	28.2 1	27. 00	26.34	55.46	49.60	48.56	30.0 9	28. 68	28.31	88.0 0	89. 00	87.00	54.5 0	52. 37	50.50
TW E	19.1 8	17.9 2	18.50	99.2 3	108. 68	109.1 1	287. 68	343.8 2	354.1 3	40.8 3	44. 07	44.66	298.2 5	354.6 2	370.4 8	41.5 7	44. 76	45.68	97.0 0	97. 00	96.00	82.6 1	89. 39	89.95
TWI	1.22	1.47	1.21	3.96	3.21	4.30	0.39	0.17	0.40	26.1 2	17. 00	25.18	0.41	0.42	0.45	26.7 6	26. 63	26.60	95.0 0	41. 00	90.00	52.5 1	22. 35	49.08
PYP P	126. 20	64.4 1	112.8 5	267. 19	240. 23	200.6 1	868. 64	1048. 63	359.3 3	15.8 8	20. 82	12.32	2099. 30	1532. 57	553.9 7	24.6 9	25. 17	15.29	41.0 0	68. 00	65.00	21.0 5	35. 48	20.43
NPP P	23.3 2	18.5 1	17.71	46.5 8	46.5 8	41.58	30.6 3	51.39	35.60	15.2 8	23. 25	22.08	45.86	59.04	39.17	18.7 0	24. 92	23.16	67.0 0	87. 00	91.00	25.7 2	44. 68	43.36
NSP P	9.17	7.68	6.16	14.6 7	14.1 0	11.33	1.58	2.01	1.64	10.0 7	12. 46	15.29	2.61	3.62	2.06	12.9 4	16. 73	17.15	61.0 0	56. 00	80.00	16.1 3	19. 11	28.09
SI	24.9 1	24.9 8	24.23	39.1 3	39.1 3	38.09	8.91	9.72	8.95	9.58	9.9 4	9.82	16.22	15.81	15.07	12.9 3	12. 68	12.74	55.0 0	62. 00	59.00	14.6 2	16. 06	15.58
SYP P	74.6 9	41.9 0	69.24	191. 21	197. 87	166.4 3	591. 56	990.3 1	476.7 7	18.5 5	28. 60	22.21	924.2 3	1304. 06	621.8 4	23.1 9	32. 82	25.37	64.0 0	76. 00	77.00	30.5 7	51. 34	40.06

PH; Plant height (m) , DFE; days to first flowering, DPI; days to pod initiation, DM; days to maturity, DFPP; days to 50% flowering, PL; Pod length (cm), PW; Pod width (cm), DPW; Dry pod weight (g), TWE; Tuber weight (g), TWI; Tuber diameter(cm), TL; Tuber length(cm), PYP; Pod yield per plant (g), NPP; Number of pod per plant, NSP ; number of seed per pod, SI ; 100 seeds weight (g), SYP; seed yield per plant (g)

4.5. Correlation Coefficient Analysis

Correlation is the degree of association of one character with the other and determines how these characters vary together or whether there is any relationship between any two such characters. Some of the characters are highly correlated in such a way that any change in one is accompanied by change in the other. Knowledge of this correlation effect is considered to be of paramount importance in crop improvement programme.

Correlation coefficient analysis was carried out for sixteen traits excluding biological yield/plant since it is derived trait calculated from stover yield and seed yield per plant so it affects the association studies. Thus, association studies undertaken in order to out the magnitude and direction of relationship of the yield contributing traits with yield and their inter-relationship. Correlation coefficient analysis measures the mutual relationship between various yield and yield contributing traits also, determines the component traits on which selection can be made for genetic improvement in yield.

A correlation coefficient analysis was worked out for all the traits in the present study at phenotypic and genotypic level and has been presented in Table 4.4 and 4.5; Fig. 4.2 (a) and 4.2 (b). Correlation analysis showed that both phenotypic and genotypic correlation for almost all the character pairs which are in the same direction. From the association studies of forty genotypes, it was clear that genotypic correlation for all the characters was more than that of phenotypic correlation but in the different proportions, indicating inherent association between the traits and elimination of environmental effects leads to strengthened the genetic association.

From the perusal of Table 4.4 and 4.5,

4.5.1. Correlation coefficient analysis at phenotypic level

4.5.1.1. Plant height

Plant height (table 4.4) exhibited profoundly significant and positive association with seed yield per plant in timely (0.203), late (0.236) and very late condition (0.169) respectively. Plant height exhibited significant and positive association with Pod yield per plant (0.264), number of pods per plant (0.231) and number of seeds per pod (0.153) in late sown condition and with Pod yield per plant (0.154), 100 seed weight (g) (0.190) and dry pod weight (g) (0.182) in very late sown condition.

Plant height exhibited significant and negative association with tuber weight (-0.233, -0.208 and -0.274), tuber width (-0.279, -0.193 and -0.193) in all three conditions respectively. In late condition it is negatively significant association with pod length (-0.205) and tuber length (-0.203) and in very late sown condition negatively significant association with pod width (-0.236).

4.5.1.2. Days to first flowering

Days to first flowering (table 4.4) exhibited highly significant and positive association with days to 50% flowering (0.831, 0.914 and 0.903), Days to pod initiation (0.940, 0.914 and 0.978), days to maturity (0.676, 0.773 and 0.724), pod length (0.248, 0.203 and 0.225) and tuber weight (0.211, 0.283 and 0.243) all three conditions respectively.

Days to first flowering (table 4.4) exhibited significant and negative association with number of pods per plant (-0.163, -0.258 and -0.352) and seed yield per plant (g) (-0.185, -0.278 and -0.254) all three conditions respectively and with pod yield per plant (-0.290 and -0.297) in late and very late conditions only.

4.5.1.3. Days to 50% flowering

Days to 50% flowering (table 4.4) exhibited highly significant and positive association with days to pod initiation (0.848, 0.925 and 0.908), days to

maturity (0.760, 0.865 and 0.798), pod length (0.237, 0.178 and 0.229) and tuber weight (0.273, 0.309 and 0.262) in all three conditions and with number of seeds per pod (0.167 and 0.176) in late and very late conditions. Days to 50% flowering exhibited significant and positive association with pod width (0.145) only in late sown condition.

Days to 50% flowering exhibited significant and negative association with Pod yield per plant (-0.189, -0.186 and -0.238), number of pods per plant (-0.261, -0.165 and -0.311) and seed yield per Plant (g) (-0.165, -0.149 and -0.131) in all three conditions respectively.

4.5.1.4. Days to Pod initiation

Days to pod initiation (table 4.4) exhibited highly significant and positive association with days to maturity (0.719, 0.814 and 0.748), pod length (0.261, 0.181 and 0.235) and tuber weight (0.236, 0.259 and 0.240) in all three conditions respectively.

Days to pod initiation exhibited significant and negative association with Pod yield per plant (-0.217, -0.288 and -0.304), number of pods per plant (-0.289, -0.257 and -0.352) and seed yield per Plant (g) (-0.261, -0.267 and -0.229) in all three conditions respectively and with dry pod weight (g) in late sown condition only.

4.5.1.5. Days to maturity

Days to maturity (table 4.4) exhibited significant and positive association with pod length (0.231, 0.218 and 0.203), tuber length (0.190, 0.152 and 0.210), tuber weight (0.142, 0.204 and 0.202) and 100 seed weight (g) (0.176, 0.165 and 0.208) in all three conditions respectively. Days to maturity exhibited significant and positive association with number of seeds per pod (0.157 and 0.279) in late and very late sown condition respectively.

Days to maturity exhibited significant and negative association with number of pods per plant (-0.315, -0.133 and -0.286) in all three conditions respectively. Days to maturity exhibited significant and negative association

with pod width (-0.141), dry pod weight (g) (-0.172), Pod yield per plant (-0.141) and seed yield per plant (g) (-0.133) in timely sown condition.

4.5.1.6. Pod length (cm)

Pod length (table 4.4) exhibited significant and positive association with dry pod weight (g) (0.267, 0.288 and 0.314), number of seeds per pod (0.218, 0.291 and 0.380) and 100 seed weight (g) (0.184, 0.170 and 0.268) in all three conditions and with seed yield per Plant (g) (0.210) in very late sown condition respectively.

Pod length exhibited significant and negative association with tuber weight (-0.150, -0.161 and -0.169) and number of pods per plant (-0.192, -0.164 and -0.164) in all three conditions respectively.

4.5.1.7. Pod width

Pod width exhibited significant and positive association with tuber weight (0.271 and 0.169) in late and very late sown condition. PW exhibited significant and positive association with tuber width (0.137) and number of pods per plant (0.185) in timely sown condition. PW exhibited significant and positive association with 100 seed weight (g) in very late sown condition.

Pod width exhibited significant and negative association with tuber length in all three conditions respectively. Tuber length significant and negative association with 100 seed weight (g) (-0.199 and -0.218) in timely and late and with Pod yield per plant (-0.130) and number of pods per plant (-0.150) in very late sown condition respectively.

4.5.1.8. Dry pod weight (g)

Dry pod weight (g) exhibited significant and positive association with 100 seed weight (g) (0.175, 0.141 and 0.235) and seed yield per plant (g) (0.166, 0.155 and 0.306) in all three conditions respectively. Dry pod weight exhibited significant and positive association with pod yield per Plant (g) (0.162 and 0.141) in late and very late conditions and with number of pods per plant (0.176) and number of seeds per pod (0.217) only in very late sown condition.

Dry pod weight (g) exhibited significant and negative association with tuber weight (-0.188 and -0.138) in timely and late sown conditions. dry pod weight (g) exhibited significant and negative association with tuber width (-0.151 and -0.225) in timely and very late sown conditions. Dry pod weight exhibited significant and negative association with tuber length (-0.193) in timely sown condition.

4.5.1.9. Tuber length

Tuber length (table 4.4) exhibited highly significant and positive association with tuber weight (0.171, 0.176 and 0.166) in all three conditions respectively. Tuber length also exhibited significant and positive association with tuber width (0.183) in late and with 100 seed weight (g) (0.160) in very late sown condition respectively.

Tuber length exhibited significant and negative association with Pod yield per plant (-0.134) and number of seeds per pod (-0.164) only in late sown condition.

4.5.1.10. Tuber weight (g)

Tuber weight (table 4.4) exhibited significant and positive association with number of seeds per pod (0.146) in late sown condition. Tuber weight exhibited significant and negative association with number of pods per plant (-0.144 and -0.168) in late and very late sown condition.

4.5.1.11. Tuber width (cm)

Tuber width (table 4.4) exhibited significant and negative association with number of pods per plant (-0.147) in timely, with number of seeds per pod (-0.155) and seed yield per Plant (g) (-0.135) in late and with seed yield per Plant (g) (-0.136) in very late sown condition respectively.

4.5.1.12. Pod yield per plant

Pod yield per plant (table 4.4) exhibited highly significant and positive association with number of pods per plant (0.409, 0.716 and 0.481), number of seeds per pod (0.332, 0.472 and 0.297), 100 seed weight (g) (0.267, 0.359 and

0.385) and seed yield per plant (g) (0.518, 0.899 and 0.630) in all three conditions respectively.

4.5.1.13. Number of pods per plant

Number of pods per plant (table 4.4) revealed significant and positive association towards seed yield per plant (g) (0.604, 0.729 and 0.533) in all three conditions respectively.

Number of pods per plant exhibited significant and negative association with 100 seed weight (g) (-0.167) only in timely sown condition.

4.5.1.14. Number of seeds per pod

Number of seeds per pod (table 4.4) exhibited significant and positive association with 100 seed weight (g) (0.195, 0.137 and 0.181) and seed yield per plant (0.418, 0.492 and 0.630) in all three conditions respectively.

4.5.1.15. 100 seed weight (g)

100 seed weight (g) exhibited (table 4.4) significant and positive association with seed yield per Plant (g) (0.423, 0.459 and 0.481) in all three conditions respectively.

4.5.2. Correlation coefficient analysis at genotypic level:

4.5.2.1. Plant height (m)

Plant height (table 4.5) exhibited significant and positive association with dry pod weight (g) (0.329, 0.326 and 0.208) and SYPP (0.172, 0.293 and 0.224) in all three conditions respectively. PH exhibited significant and positive association with pod yield per plant (0.258), (0.216) in late and very late condition, with number of seeds per pod (0.159) in timely sown condition, with number of pods per plant (0.203) in late condition and with 100 seed weight (g) (0.256) in very late condition respectively.

Plant height exhibited significant and negative association with tuber length (-0.301, -0.349 and -0.261) and tuber weight (-0.302, -0.335 and -0.304) in all three conditions, with pod width (-0.145 and -0.280) in timely and very

late condition and with days to first flowering (-0.160), days to 50% flowering (-0.131) and days to pod initiation (-0.214) in late condition respectively.

4.5.2.2. Days to first flowering

Days to first flowering (table 4.5) exhibited significant and positive association with days to 50% flowering (0.962, 0.930 and 0.642), days to maturity (0.792, 0.787 and 0.722), pod length (0.310, 0.260 and 0.290) and tuber weight (0.255, 0.265 and 0.257) in all three conditions respectively. Days to first flowering exhibited significant and positive association with DPI (0.958 and 0.794) in late and very late condition.

Days to first flowering exhibited significant and negative association with Pod yield per plant (-0.494, -0.470 and -0.419), number of pods per plant (-0.412, -0.390 and -0.373) and seed yield per Plant (g) (-0.401, -0.401 and -0.275) in all three conditions respectively. Days to first flowering exhibited significant and negative association with dry pod weight (-0.181) and number of seeds per pod (-0.199) in timely and late condition respectively.

4.5.2.3. Days to 50% flowering

Days to 50% flowering (table 4.5) exhibited highly significant and positive association with DPI (0.966, 0.955 and 0.963), DM (0.900, 0.886 and 0.712), pod length (0.279, 0.222 and 0.288) and tuber weight (0.334, 0.292 and 0.288) in all three conditions respectively. Days to 50% flowering exhibited significant and positive association towards number of seeds per pod (0.220) and 100 seed weight (g) (0.127) in very late sown condition.

Days to 50% flowering exhibited significant and negative association with Pod yield per plant (-0.406, -0.383 and -0.325), number of pods per plant (-0.402, -0.325 and -0.334) and seed yield per plant (g) (-0.321, -0.277 and -0.176) in all three conditions and with dry pod weight (g) (-0.285 and -0.188) timely and late sown conditions respectively.

4.5.2.4. Days to pod initiation

Days to pod initiation (table 4.5) exhibited significant and positive association with days to maturity (0.797, 0.844 and 0.740), pod length (0.310, 0.223 and 0.287) and tuber weight (0.262, 0.234 and 0.256) in all three conditions.

Days to pod initiation exhibited significant and negative association with Pod yield per plant (-0.457, -0.491 and -0.411), number of pods per plant (-0.387, -0.396 and -0.361) and seed yield per plant (g) (-0.364, -0.396 and -0.259) in all three conditions and with dry pod weight (g) (-0.158 and -0.149) in timely and late sown condition respectively.

4.5.2.5. Days to maturity

Days to maturity showed (table 4.5) significant and positive association with pod length (0.297, 0.298 and 0.256), tuber length (0.198, 0.184 and 0.261) and 100 seed weight (g) (0.210, 0.218 and 0.239) in all three conditions and with tuber weight (0.166 and 0.224) in timely and very late sown condition respectively.

Days to maturity showed significant and negative association with Pod yield per plant (-0.339, -0.342 and -0.238) and number of pods per plant (-0.418, -0.341 and -0.289) in all three conditions, with seed yield per Plant (g) (-0.192 and -0.264) in timely and late sown condition, with PW (-0.369 and -0.138) in timely and late sown condition, with tuber width (-0.142 and -0.188) in late and very late sown condition and with dry pod weight (g) (-0.180) in timely sown condition respectively.

4.5.2.6. Pod length (cm)

Pod length exhibited (table 4.5) significant and positive association with dry pod weight (g) (0.373, 0.377 and 0.408), number of seeds/pod (0.306, 0.416 and 0.561) and with 100 seed weight (g) (0.425, 0.372 and 0.442) in all three conditions, with Pod yield per plant (0.152 and 0.134) in timely and late sown

condition, with seed yield per plant (0.126 and 0.353) in late and very late and with pod width (0.171) in very late sown condition respectively.

Pod length exhibited significant as well as negative association with tuber weight (-0.157, -0.194 and -0.193) and number of pods/plant (-0.285, -0.198 and -0.182) in all three conditions.

4.5.2.7. Pod width (cm)

Pod width exhibited (table 4.5) significant and positive association with tuber weight (0.274 and 0.179) in late and very late condition, and with tuber width (0.171) and number of pods per plant (0.302) in timely sown condition respectively.

Pod width exhibited significant and negative association on tuber length (-0.193, -0.185 and -0.147) in all three conditions, seed yield per plant (-0.221 and -0.325) in timely sown condition, with tuber width (-0.294), Pod yield per plant (-0.196), 100 seed weight (g) (-0.325) and seed yield per plant (g) (-0.156) in late sown condition and with number of pods per plant (-0.166) and seed yield per Plant (g) (-0.154) in very late condition respectively.

4.5.2.8. Dry pod weight (g)

Dry pod weight (g) (table 4.5) exhibited significant and positive association with the seed yield/plant (g) (0.205, 0.222 and 0.359) in all three conditions, with 100 seed weight (g) (0.187) in timely sown condition, with Pod yield per plant (0.241) in late sown condition and with pod yield per plant (0.155), number of pods per plant (0.155), number of seeds per pod (0.232) and 100 seed weight (g) (0.271) in very late condition respectively.

Dry pod weight exhibited significant and negative association with tuber width (-0.169, -0.239 and -0.253) in all three conditions, with tuber length (-0.214) in timely sown condition and with tuber length (-0.149) and tuber weight (-0.149) in late condition respectively.

4.5.2.9. Tuber length

Tuber length (table 4.5) exhibited significant as well as positive association with tuber weight (0.184 and 0.174) in late sown condition and very late condition, with tuber width (0.369) in the late sown condition and with 100 seed weight (g) (0.146) in very late condition respectively.

Tuber length exhibited significant and negative association with number of seeds per pod (-0.197 and -0.251) and seed yield per Plant (g) (-0.137 and -0.130) during timely and late sown condition and with Pod yield per plant (-0.194) in late sown condition respectively.

4.5.2.10. Tuber weight (g)

Tuber weight (table 4.5) exhibited significant and positive association with number of seeds per pod (0.135) in late sown condition.

Tuber weight exhibited significant and negative association with number of pods per plant (-0.186 and -0.181) in late and very late sown condition and with tuber width (-0.198) in late sown condition respectively.

4.5.2.11. Tuber Width (cm)

Tuber width (table 4.5) exhibited significant and negative association with Pod yield per plant (-0.184, -0.184) and seed yield per plant (g) (-0.130 and -0.208) in late and very late sown condition, with number of pods per plant (-0.204) in timely sown condition and with number of seeds per pod (-0.166) in late sown condition respectively.

4.5.2.12. Pod yield per plant

Pod yield per plant (table 4.5) exhibited highly significant and positive association with number of pods per plant (0.559, 0.770 and 0.614), number of seeds per pod (0.424, 0.399 and 0.348), 100 seed weight (g) (0.243, 0.324 and 0.395) and seed yield per Plant (g) (0.724, 0.946 and 0.765) in all three conditions respectively.

4.5.2.13. Number of pods per plant

Number of pods per plant (table 4.5) exhibited significant and positive association with seed yield per Plant (g) (0.707, 0.777 and 0.607) in all three conditions respectively.

Number of pods per plant exhibited significant and negative association with 100 seed weight (g) (-0.163) in timely sown conditions.

Table 4.4: Phenotypic correlation among yield and yield attributing traits of winged bean

		PH	DFE	DFPF	DPI	DM	PL	PW	DPW	TL	TWE	TWI	PYPP	NPPP	NSPP	SI	SYPP
PH	T		0.0213	0.016	-0.031	0.026	0.043	-0.136 *	0.264	0.150 *	-0.233 ***	-0.279 ***	-0.039	0.114	0.006	0.106	0.203***
	L		-0.012	0.055	-0.047	0.105	-0.005***	0.099	0.281	-0.240 ***	-0.208 ***	-0.193 **	0.264 ***	0.231 ***	0.153 *	0.111	0.236***
	VL		-0.035	-0.023	-0.006	0.028	0.069	-0.236 ***	0.182 **	-0.203 **	-0.274 ***	-0.193 **	0.154 *	0.085	0.091	0.190 **	0.169**
DFE	T			0.831 ***	0.940 ***	0.676 ***	0.248 ***	-0.027	-0.135 *	0.077	0.211 ***	0.102	-0.126	-0.163 *	-0.092	-0.010	-0.185**
	L			0.914 ***	0.914 ***	0.773 ***	0.203 **	0.101	-0.091	0.052	0.283 ***	0.033	-0.290 ***	-0.258 ***	0.077	0.010	-0.278***
	VL			0.903 ***	0.978 ***	0.724 ***	0.225 ***	0.058	-0.096	0.024	0.243 ***	0.025	-0.297 ***	-0.352 ***	0.082	0.036	-0.254***
DFPF	T				0.848 ***	0.760 ***	0.237 ***	-0.133 *	-0.218 ***	0.123	0.273 ***	0.000	-0.189 **	-0.261 ***	0.076	0.038	-0.165**
	L				0.925 ***	0.865 ***	0.178 **	0.145 *	-0.149 *	0.108	0.309 ***	-0.004	-0.186 **	-0.165 *	0.167 **	0.093	-0.149*
	VL				0.908 ***	0.798 ***	0.229 ***	0.025	-0.092	0.075	0.262 ***	-0.088	-0.238 ***	-0.311 ***	0.176 **	0.101	-0.131*
DPI	T					0.719 ***	0.261 ***	-0.027	-0.121	0.069	0.236 ***	0.075	-0.217 ***	-0.289 ***	-0.111	0.014	-0.261***
	L					0.814 ***	0.181 **	0.074	-0.136 *	0.100	0.259 ***	0.0005	-0.288 ***	-0.257 ***	0.090	0.057	-0.267***
	VL					0.748 ***	0.235 ***	0.064	-0.065	0.033	0.240 ***	-0.001	-0.304 ***	-0.352 ***	0.100	0.049	-0.229***
DM	T						0.231 ***	-0.269 ***	-0.172 **	0.190 **	0.142 *	-0.078	-0.141 *	-0.315 ***	-0.005	0.176 **	-0.133**
	L						0.218 ***	0.075	-0.054	0.152 *	0.204 **	-0.070	-0.080	-0.133 *	0.157 *	0.165 *	-0.097
	VL						0.203 **	-0.011	-0.019	0.210 **	0.202 **	-0.163 *	-0.148 *	-0.286 ***	0.279 ***	0.208 **	0.0001
PL	T							0.036	0.267 ***	-0.055	-0.150 *	-0.015	0.055	-0.192 **	0.218 ***	0.184 **	0.046
	L							-0.001	0.288 ***	-0.025	-0.161 *	-0.108	0.046	-0.164 *	0.291 ***	0.170 **	0.0599
	VL							0.125	0.314 ***	0.0263	-0.169 **	-0.004	0.006	-0.164 *	0.380 ***	0.268 ***	0.210***
PW	T								0.054	-0.164 *	0.071	0.137 *	0.036	0.185 **	-0.038	-0.199 **	0.050
	L								0.055	-0.152 *	0.271 ***	-0.065	-0.083	-0.007	0.125	-0.218 ***	-0.096
	VL								0.015	-0.108	0.169 **	0.073	-0.130 *	-0.150 *	-0.027	-0.111	-0.108
DPW	T									-0.193 **	-0.188 **	-0.151 *	0.050	0.015	0.028	0.175 **	0.166**

	L									-0.124	-0.138 *	-0.109	0.162 *	0.091	0.024	0.141 *	0.155*
	VL									-0.055	-0.005	-0.225 ***	0.141 *	0.176 **	0.217 ***	0.235 ***	0.306***
TL	T										0.171 **	0.016	-0.040	-0.021	-0.118	0.088	-0.031
	L										0.176 **	0.183 **	-0.134 *	-0.009	-0.164 *	0.048	-0.083
	VL										0.166 **	0.009	-0.056	-0.076	-0.018	0.160 *	-0.017
TWE	T											-0.059	-0.036	-0.092	0.0546	0.002	-0.034
	L											-0.116	-0.049	-0.144 *	0.146 *	0.067	-0.045
	VL											-0.105	-0.082	-0.168 **	0.026	0.027	-0.070
TWI	T												-0.025	-0.147 *	-0.002	0.029	-0.098
	L												-0.115	-0.040	-0.155 *	-0.072	-0.135*
	VL												-0.104	-0.080	-0.105	-0.045	-0.136*
PYPP	T													0.409 ***	0.332 ***	0.267 ***	0.518***
	L													0.716 ***	0.472 ***	0.359 ***	0.899***
	VL													0.481 ***	0.297 ***	0.385 ***	0.630***
NPPP	T														0.114	-0.167 **	0.604***
	L														0.029	-0.0001	0.729***
	VL														0.034	0.01	0.533***
NSPP	T															0.195 **	0.418***
	L															0.137 *	0.492***
	VL															0.181 **	0.630***
SI	T																0.423***
	L																0.459***
	VL																0.481***

Table 4.5: Genotypic correlation among yield and yield attributing traits of winged bean

		PH	DFP	DFPF	DPI	DM	PL	PW	DPW	TL	TWE	TWI	PYPP	NPPP	NSPP	SI	SYPP
PH	T		-0.113	-0.031	-0.061	0.051	0.012	-0.145*	0.329***	- 0.301***	- 0.302***	-0.058	0.023	-0.103	0.159*	0.165	0.172**
	L		- 0.160**	-0.131*	- 0.214***	-0.092	0.006	-0.099	0.326***	- 0.349***	- 0.335***	-0.474	0.258***	0.203***	0.100	0.166	0.293***
	VL		-0.060	-0.033	-0.024	0.042	0.083	- 0.280***	0.208***	- 0.261***	- 0.304***	-0.207	0.216***	0.111	0.117	0.256***	0.224***
DFP	T			0.962***	0.010	0.792***	0.310***	-0.109	- 0.181***	0.082	0.255***	0.103	- 0.494***	- 0.412***	- 0.199***	0.013	- 0.401***
	L			0.930***	0.958***	0.787***	0.260***	-0.015	-0.117	0.076	0.265***	-0.021	- 0.470***	- 0.390***	-0.083	0.052	- 0.401***
	VL			0.642***	0.794***	0.722***	0.290***	0.055	-0.116	0.034	0.257***	-0.002	- 0.419***	- 0.373***	0.098	0.083	- 0.275***
DFPF	T				0.966***	0.900***	0.279***	- 0.227***	- 0.285***	0.112	0.334***	0.013	- 0.406***	- 0.402***	-0.093	0.042	- 0.321***
	L				0.955***	0.886***	0.222***	-0.003	- 0.188***	0.121	0.292***	-0.077	- 0.383***	- 0.325***	0.002	0.121	- 0.277***
	VL				0.963***	0.712***	0.288***	0.025	-0.113	0.088	0.288***	-0.121	- 0.325***	- 0.334***	0.220***	0.127*	-0.176**
DPI	T					0.797***	0.310***	-0.117	-0.158*	0.089	0.262***	0.086	- 0.457***	- 0.387***	-0.169	0.031	- 0.364***
	L					0.844***	0.223***	-0.036	-0.149*	0.098	0.234***	0.026	- 0.491***	- 0.396***	-0.070	0.075	- 0.396***
	VL					0.740***	0.287***	0.059	-0.085	0.037	0.256***	-0.022	- 0.411***	- 0.361***	0.114	0.077	- 0.259***
DM	T						0.297***	- 0.369***	- 0.180***	0.198***	0.166**	-0.084	- 0.339***	- 0.418***	-0.037	0.210***	- 0.192***
	L						0.298***	-0.138*	-0.062	0.184***	0.174	-0.142*	- 0.342***	- 0.341***	-0.076	0.218***	- 0.264***
	VL						0.256***	-0.023	-0.050	0.261***	0.224***	- 0.188***	- 0.238***	- 0.289***	0.361***	0.239***	-0.018
PL	T							-0.042	0.373***	-0.094	-0.157*	-0.011	0.152*	- 0.285***	0.306***	0.425***	0.054
	L							0.014	0.377***	-0.047	- 0.194***	-0.116	0.134*	- 0.198***	0.416***	0.372***	0.126*
	VL							0.171**	0.408***	0.012	- 0.193***	0.045	0.091	- 0.182***	0.561***	0.442***	0.353***

PW	T								0.040	- 0.193***	0.100	0.171**	0.119	0.302***	-0.034	- 0.221***	0.207
	L								0.049	- 0.185***	0.274***	- 0.294***	- 0.196***	-0.093	0.092	- 0.325***	-0.156*
	VL								-0.017	-0.147*	0.179**	0.079	-0.202	-0.166**	-0.052	-0.201	-0.154*
DPW	T									- 0.214***	-0.213	-0.169**	0.104	0.060	0.047	0.187***	0.205***
	L									-0.149*	-0.149*	- 0.239***	0.241***	0.132	0.123	0.118	0.222***
	VL									-0.100	-0.028	- 0.253***	0.155*	0.213***	0.232***	0.271***	0.359***
TL	T										0.191	0.018	-0.011	-0.072	- 0.197***	0.064	-0.137*
	L										0.184***	0.369***	- 0.194***	-0.008	- 0.251***	-0.007	-0.130*
	VL										0.174**	0.004	-0.113	-0.077	-0.024	0.146*	-0.040
TWE	T											-0.061	-0.029	-0.111	0.079	0.002	-0.050
	L											- 0.198***	-0.098	- 0.186***	0.135*	0.079	-0.079
	VL											-0.099	-0.108	- 0.181***	0.018	0.028	-0.086
TWI	T												-0.058	- 0.204***	-0.008	0.037	-0.138
	L												- 0.184***	-0.018	-0.166**	-0.134	-0.130*
	VL												- 0.184***	-0.107	-0.145	-0.086	- 0.208***
PYPP	T													0.559***	0.424***	0.243***	0.724***
	L													0.770***	0.399***	0.324***	0.946***
	VL													0.614***	0.348***	0.395***	0.765***
NPPP	T														0.095	-0.163**	0.707***
	L														-0.118	-0.020	0.777***

	VL														0.029	0.006	0.607***
NSPP	T															0.341***	0.539***
	L															0.271***	0.431***
	VL															0.335***	0.712***
SI	T																0.431***
	L																0.440***
	VL																0.496***

Table 4.6. Estimate of direct (diagonal) and indirect effects of yield component at Phenotypic level in winged bean genotypes

Traits		PH	DFE	DFPF	DPI	DM	PL	PW	DPW	TL	TWE	TWI	PYPP	NPPP	NSPP	SI	SYPP
PH	Timely	0.1322	0.0028	0.0022	-0.004	0.0035	0.0057	-0.018	0.035	-0.031	-0.037	-0.005	0.0151	0.0008	0.0199	0.0141	0.2027***
	Late	-0.051	0.0006	-0.003	0.0024	-0.005	0.0003	-0.005	-0.014	0.0123	0.0107	0.0099	-0.014	-0.012	-0.008	-0.006	0.2365***
	Very late	-0.003	0.0001	0.0001	0	-1E-04	-2E-04	0.0007	-5E-04	0.0006	0.0008	0.0006	-5E-04	-3E-04	-3E-04	-6E-04	0.1695**
DFE	Timely	-0.002	-0.106	-0.088	-0.1	-0.072	-0.026	0.0029	0.0143	-0.008	-0.023	-0.011	0.0134	0.0174	0.0099	0.0011	-0.1849**
	Late	0.0001	-0.005	-0.005	-0.005	-0.004	-0.001	-5E-04	0.0005	-3E-04	-0.002	-2E-04	0.0015	0.0013	-4E-04	-1E-04	-0.2779***
	Very late	0.0133	-0.376	-0.339	-0.367	-0.272	-0.084	-0.022	0.0363	-0.009	-0.091	-0.01	0.1115	0.1325	-0.031	-0.014	-0.2546***
DFPF	Timely	0.0009	0.0455	0.0548	0.0465	0.0416	0.013	-0.007	-0.012	0.0068	0.015	0	-0.01	-0.014	0.0042	0.0021	-0.1636**
	Late	0.0058	0.0966	0.1057	0.0977	0.0914	0.0188	0.0153	-0.016	0.0114	0.0327	-5E-04	-0.02	-0.018	0.0177	0.0099	-0.1499*
	Very late	-0.002	0.0589	0.0652	0.0592	0.0521	0.015	0.0016	-0.006	0.0049	0.0171	-0.006	-0.016	-0.02	0.0115	0.0066	-0.1308*
DPI	Timely	0.0025	-0.076	-0.069	-0.081	-0.058	-0.021	0.0022	0.0099	-0.006	-0.019	-0.006	0.0176	0.0234	0.009	-0.001	-0.2610***
	Late	0.0074	-0.142	-0.144	-0.155	-0.126	-0.028	-0.012	0.0212	-0.016	-0.04	-1E-04	0.0448	0.0399	-0.014	-0.009	-0.2672***
	Very late	-0.001	0.1697	0.1575	0.1734	0.1299	0.0407	0.0112	-0.011	0.0057	0.0417	-2E-04	-0.053	-0.061	0.0174	0.0086	-0.2295***
DM	Timely	0.0022	0.0567	0.0638	0.0604	0.0839	0.0194	-0.023	-0.015	0.016	0.0119	-0.007	-0.012	-0.027	-5E-04	0.0148	-0.1335**
	Late	-0.008	-0.059	-0.066	-0.062	-0.077	-0.017	-0.006	0.0041	-0.012	-0.016	0.0054	0.0062	0.0102	-0.012	-0.013	-0.097
	Very late	0.0002	0.006	0.0066	0.0062	0.0083	0.0017	-1E-04	-2E-04	0.0017	0.0017	-0.001	-0.001	-0.002	0.0023	0.0017	0.0001
PL	Timely	0.0024	0.0139	0.0133	0.0146	0.013	0.056	0.002	0.015	-0.003	-0.008	-8E-04	0.0031	-0.011	0.0122	0.0103	0.046
	Late	0	-0.001	-9E-04	-9E-04	-0.001	-0.005	0	-0.001	0.0001	0.0008	0.0005	-2E-04	0.0008	-0.001	-8E-04	0.0599
	Very late	0.0015	0.005	0.0051	0.0052	0.0045	0.0221	0.0028	0.0069	0.0006	-0.004	-1E-04	0.0001	-0.004	0.0084	0.0059	0.2106***
PW	Timely	-0.007	-0.002	-0.007	-0.002	-0.014	0.0019	0.0534	0.0029	-0.009	0.0038	0.0073	0.002	0.0099	-0.002	-0.011	0.0504
	Late	-0.005	-0.005	-0.007	-0.003	-0.003	0.0001	-0.045	-0.003	0.0069	-0.012	0.0029	0.0037	0.0003	-0.006	0.0098	-0.0966
	Very late	-0.005	0.0012	0.0005	0.0013	-2E-04	0.0025	0.02	0.0003	-0.002	0.0034	0.0015	-0.003	-0.003	-5E-04	-0.002	-0.1086
DPW	Timely	0.0099	-0.005	-0.008	-0.005	-0.006	0.01	0.002	0.0373	-0.007	-0.007	-0.006	0.0019	0.0006	0.0011	0.0065	0.1667**
	Late	0.0062	-0.002	-0.003	-0.003	-0.001	0.0064	0.0012	0.0222	-0.003	-0.003	-0.002	0.0036	0.002	0.0005	0.0031	0.1556*
	Very late	-6E-04	0.0003	0.0003	0.0002	0.0001	-0.001	-1E-04	-0.004	0.0002	0	0.0008	-5E-04	-6E-04	-8E-04	-8E-04	0.3060***
TL	Timely	0.0015	-5E-04	-8E-04	-4E-04	-0.001	0.0003	0.001	0.0012	-0.006	-0.001	-1E-04	0.0003	0.0001	0.0007	-6E-04	-0.0309
	Late	0.0025	-6E-04	-0.001	-0.001	-0.002	0.0003	0.0016	0.0013	-0.011	-0.002	-0.002	0.0014	0.0001	0.0017	-5E-04	-0.0835
	Very late	0.0061	-7E-04	-0.002	-0.001	-0.006	-8E-04	0.0033	0.0017	-0.03	-0.005	-3E-04	0.0017	0.0023	0.0006	-0.005	-0.0169
TWE	Timely	-0.023	0.0174	0.0224	0.0194	0.0117	-0.012	0.0059	-0.016	0.0141	0.0822	-0.005	-0.003	-0.008	0.0045	0.0002	-0.0341
	Late	0.0013	-0.002	-0.002	-0.002	-0.001	0.001	-0.002	0.0009	-0.001	-0.006	0.0007	0.0003	0.0009	-9E-04	-4E-04	-0.0457
	Very late	-0.006	0.0051	0.0055	0.005	0.0042	-0.004	0.0035	-1E-04	0.0035	0.0209	-0.002	-0.002	-0.004	0.0006	0.0006	-0.0708

TWI	Timely	-7E-04	0.0019	0	0.0014	-0.001	-3E-04	0.0025	-0.003	0.0003	-0.001	0.0184	-5E-04	-0.003	0	0.0005	-0.0984
	Late	0.0048	-8E-04	0.0001	0	0.0017	0.0027	0.0016	0.0027	-0.005	0.0029	-0.025	0.0029	0.001	0.0039	0.0018	-0.1353*
	Very late	0.001	-1E-04	0.0005	0	0.0009	0	-4E-04	0.0012	0	0.0005	-0.005	0.0005	0.0004	0.0005	0.0002	-0.1363*
PYPP	Timely	0.0051	-0.006	-0.009	-0.01	-0.006	0.0025	0.0017	0.0023	-0.002	-0.002	-0.001	0.0449	0.0184	0.0149	0.012	0.5186***
	Late	0.0331	-0.036	-0.023	-0.036	-0.01	0.0058	-0.01	0.0204	-0.017	-0.006	-0.015	0.1253	0.0898	0.0592	0.0451	0.8999***
	Very late	0.0159	-0.031	-0.025	-0.032	-0.015	0.0006	-0.014	0.0146	-0.006	-0.009	-0.011	0.1035	0.0498	0.0308	0.0399	0.6305***
NPPP	Timely	0.004	-0.106	-0.17	-0.188	-0.205	-0.125	0.1205	0.0102	-0.014	-0.06	-0.096	0.2658	0.649	0.0742	-0.109	0.6039***
	Late	0.1394	-0.155	-0.1	-0.155	-0.08	-0.099	-0.004	0.0552	-0.006	-0.087	-0.024	0.4309	0.6014	0.0176	-1E-04	0.7296***
	Very late	0.0359	-0.149	-0.131	-0.149	-0.121	-0.069	-0.064	0.0744	-0.032	-0.071	-0.034	0.2029	0.4218	0.0145	0.0042	0.5330***
NSPP	Timely	0.0277	-0.017	0.014	-0.02	-0.001	0.04	-0.007	0.0053	-0.022	0.01	-4E-04	0.061	0.021	0.1834	0.0358	0.4187***
	Late	0.0587	0.0298	0.0641	0.0346	0.0604	0.1116	0.0481	0.0095	-0.063	0.0562	-0.06	0.181	0.0112	0.3835	0.0528	0.4922***
	Very late	0.0469	0.0426	0.0907	0.0516	0.1436	0.1953	-0.014	0.1118	-0.01	0.0137	-0.054	0.1529	0.0177	0.514	0.0935	0.6303***
SI	Timely	0.0476	-0.005	0.017	0.0062	0.0785	0.0821	-0.089	0.0781	0.0392	0.001	0.0131	0.1192	-0.075	0.0872	0.4464	0.4227***
	Late	0.0409	0.0037	0.0343	0.021	0.0604	0.0625	-0.08	0.0518	0.0178	0.0248	-0.027	0.1318	-1E-04	0.0505	0.3664	0.4598***
	Very late	0.0654	0.0126	0.0345	0.017	0.0715	0.0921	-0.038	0.0806	0.0549	0.0093	-0.016	0.1321	0.0034	0.0623	0.3427	0.4817***
Partial R ²	Timely	0.0268	0.0196	-0.009	0.0211	-0.011	0.0026	0.0027	0.0062	0.0002	-0.003	-0.002	0.0233	0.3919	0.0768	0.1887	
	Late	-0.012	0.0014	-0.016	0.0415	0.0074	-3E-04	0.0043	0.0034	0.0009	0.0003	0.0034	0.1128	0.4387	0.1887	0.1685	
	Very late	-5E-04	0.0956	-0.009	-0.04	0	0.0047	-0.002	-0.001	0.0005	-0.002	0.0007	0.0652	0.2248	0.3239	0.1651	
RESIDUAL EFFECT	Timely	0.3715															
	Late	0.2384															
	Very late	0.4159															

Table 4.7. Estimate of direct (diagonal) and indirect effects of yield component at Genotypic level in winged bean genotypes

		PH	DFE	DFPF	DPI	DM	PL	PW	DPW	TL	TWE	TWI	PYPP	NPPP	NSPP	SI	SYPP
PH	Timely	0.0827	-0.009	-0.003	-0.005	0.0042	0.001	-0.012	0.0272	-0.025	-0.025	-0.005	0.0019	-0.009	0.0132	0.0137	0.1724
	Late	0.0225	-0.004	-0.003	-0.005	-0.002	0.0001	-0.002	0.0073	-0.008	-0.008	-0.011	0.0058	0.0046	0.0023	0.0037	0.2934***
	Very late	0.0149	-9E-04	-5E-04	-4E-04	0.0006	0.0012	-0.004	0.0031	-0.004	-0.005	-0.003	0.0032	0.0016	0.0017	0.0038	0.2241***
DFE	Timely	0.0345	-0.306	-0.295	-0.309	-0.243	-0.095	0.0333	0.0554	-0.025	-0.078	-0.032	0.1513	0.1262	0.0608	-0.004	-0.4008***
	Late	-5E-04	0.0031	0.0029	0.003	0.0024	0.0008	0	-4E-04	0.0002	0.0008	-1E-04	-0.002	-0.001	-3E-04	0.0002	-0.4007***
	Very late	-0.028	0.468	0.4512	0.465	0.3847	0.1359	0.0258	-0.054	0.016	0.12	-7E-04	-0.196	-0.175	0.0458	0.0388	-0.2752***
DFPF	Timely	0.0024	-0.077	-0.08	-0.077	-0.072	-0.022	0.0181	0.0227	-0.009	-0.027	-0.001	0.0323	0.032	0.0074	-0.003	-0.3208***
	Late	-0.015	0.1036	0.1114	0.1065	0.0987	0.0247	-3E-04	-0.021	0.0135	0.0325	-0.009	-0.043	-0.036	0.0002	0.0134	-0.2765***
	Very late	0.0279	-0.815	-0.846	-0.815	-0.771	-0.244	-0.021	0.0955	-0.075	-0.244	0.1021	0.2749	0.2823	-0.186	-0.108	-0.1758
DPI	Timely	-0.007	0.1232	0.1179	0.122	0.0972	0.0378	-0.014	-0.019	0.0109	0.0319	0.0104	-0.056	-0.047	-0.021	0.0037	-0.3638***
	Late	0.0565	-0.253	-0.252	-0.264	-0.223	-0.059	0.0094	0.0393	-0.026	-0.062	-0.007	0.1295	0.1046	0.0184	-0.02	-0.3956***
	Very late	0.0011	-0.044	-0.043	-0.044	-0.037	-0.013	-0.003	0.0037	-0.002	-0.011	0.001	0.0182	0.016	-0.005	-0.003	-0.2589***
DM	Timely	0.0192	0.2983	0.3394	0.3003	0.3769	0.112	-0.139	-0.068	0.0748	0.0625	-0.032	-0.128	-0.157	-0.014	0.0791	-0.1919*
	Late	-0.011	0.0927	0.1043	0.0993	0.1177	0.0351	-0.016	-0.007	0.0216	0.0204	-0.017	-0.04	-0.04	-0.009	0.0257	-0.2644***
	Very late	0.0106	0.2094	0.2322	0.2139	0.2547	0.0651	-0.006	-0.013	0.0664	0.0569	-0.048	-0.061	-0.074	0.0919	0.061	-0.0178
PL	Timely	-9E-04	-0.024	-0.021	-0.024	-0.023	-0.076	0.0032	-0.029	0.0072	0.012	0.0009	-0.012	0.0218	-0.023	-0.033	0.0543
	Late	-1E-04	-0.005	-0.004	-0.004	-0.006	-0.019	-3E-04	-0.007	0.0009	0.0037	0.0022	-0.003	0.0037	-0.008	-0.007	0.1263*
	Very late	0.0113	0.0397	0.0395	0.0393	0.035	0.1368	0.0234	0.0558	0.0017	-0.026	0.0062	0.0124	-0.025	0.0768	0.0605	0.3532***
PW	Timely	-0.026	-0.019	-0.04	-0.021	-0.065	-0.007	0.1765	0.007	-0.034	0.0177	0.0302	0.0211	0.0532	-0.006	-0.039	0.2073*
	Late	-8E-04	-1E-04	0	-3E-04	-0.001	0.0001	0.0078	0.0004	-0.001	0.0021	-0.002	-0.002	-7E-04	0.0007	-0.003	-0.1557*
	Very late	0.002	-4E-04	-2E-04	-4E-04	0.0002	-0.001	-0.007	0.0001	0.0011	-0.001	-6E-04	0.0015	0.0012	0.0004	0.0015	-0.1544
DPW	Timely	0.0237	-0.013	-0.021	-0.011	-0.013	0.0269	0.0029	0.072	-0.015	-0.015	-0.012	0.0075	0.0043	0.0034	0.0135	0.2053*
	Late	0.008	-0.003	-0.005	-0.004	-0.002	0.0093	0.0012	0.0246	-0.004	-0.004	-0.006	0.0059	0.0032	0.003	0.0029	0.2215***
	Very late	-0.015	0.0085	0.0083	0.0062	0.0036	-0.03	0.0012	-0.074	0.0073	0.0021	0.0186	-0.011	-0.016	-0.017	-0.02	0.3585***
TL	Timely	0.0173	-0.005	-0.007	-0.005	-0.011	0.0054	0.0111	0.0123	-0.058	-0.011	-0.001	0.0006	0.0041	0.0114	-0.004	-0.1366*
	Late	0.0128	-0.003	-0.005	-0.004	-0.007	0.0017	0.0068	0.0055	-0.037	-0.007	-0.014	0.0072	0.0003	0.0092	0.0003	-0.1297*
	Very late	0.0093	-0.001	-0.003	-0.001	-0.009	-4E-04	0.0053	0.0036	-0.036	-0.006	-2E-04	0.004	0.0028	0.0009	-0.005	-0.0396
TWE	Timely	-0.012	0.0102	0.0133	0.0104	0.0066	-0.006	0.004	-0.009	0.0076	0.0399	-0.002	-0.001	-0.004	0.0031	0.0001	-0.0499
	Late	-0.007	0.0058	0.0064	0.0051	0.0038	-0.004	0.006	-0.003	0.004	0.0219	-0.004	-0.002	-0.004	0.0029	0.0017	-0.0787
	Very late	-0.033	0.0279	0.0313	0.0278	0.0243	-0.021	0.0194	-0.003	0.0189	0.1086	-0.011	-0.012	-0.02	0.0019	0.003	-0.0858

TWI	Timely	-0.002	0.0033	0.0004	0.0028	-0.003	-4E-04	0.0056	-0.006	0.0006	-0.002	0.0325	-0.002	-0.007	-2E-04	0.0012	-0.1383*
	Late	-0.033	-0.002	-0.005	0.0018	-0.01	-0.008	-0.021	-0.017	0.0259	-0.014	0.0701	-0.013	-0.001	-0.012	-0.009	-0.1298*
	Very late	0.0199	0.0001	0.0116	0.0021	0.0181	-0.004	-0.008	0.0244	-4E-04	0.0095	-0.097	0.0178	0.0103	0.0139	0.0083	-0.2075
PYPP	Timely	0.0034	-0.073	-0.06	-0.067	-0.05	0.0223	0.0175	0.0153	-0.002	-0.004	-0.009	0.1468	0.082	0.0622	0.0356	0.7240***
	Late	0.0139	-0.025	-0.021	-0.026	-0.018	0.0072	-0.011	0.013	-0.011	-0.005	-0.01	0.0539	0.0415	0.0215	0.0174	0.9461***
	Very late	0.0253	-0.049	-0.038	-0.048	-0.028	0.0107	-0.024	0.0181	-0.013	-0.013	-0.022	0.1174	0.0721	0.0409	0.0464	0.7645***
NPPP	Timely	-0.066	-0.266	-0.26	-0.25	-0.27	-0.185	0.195	0.0386	-0.046	-0.072	-0.132	0.3615	0.6467	0.0616	-0.105	0.7066***
	Late	0.1535	-0.295	-0.246	-0.3	-0.258	-0.15	-0.07	0.0996	-0.006	-0.141	-0.013	0.5828	0.7567	-0.09	-0.015	0.7770***
	Very late	0.0566	-0.191	-0.171	-0.184	-0.148	-0.093	-0.085	0.1087	-0.04	-0.093	-0.055	0.3139	0.5111	0.015	0.0031	0.6068***
NSPP	Timely	0.0394	-0.049	-0.023	-0.042	-0.009	0.0759	-0.009	0.0117	-0.049	0.0194	-0.002	0.105	0.0236	0.2477	0.0844	0.5385***
	Late	0.0405	-0.033	0.0007	-0.028	-0.031	0.1683	0.0372	0.0499	-0.102	0.0544	-0.067	0.1614	-0.048	0.4045	0.1095	0.4309***
	Very late	0.0655	0.0546	0.123	0.0635	0.2014	0.3133	-0.029	0.1297	-0.014	0.0098	-0.081	0.1945	0.0164	0.5583	0.1868	0.7121***
SI	Timely	0.0641	0.005	0.0165	0.0119	0.0815	0.165	-0.086	0.0726	0.025	0.0006	0.0144	0.0942	-0.063	0.1321	0.3879	0.4313***
	Late	0.053	0.0164	0.0384	0.0238	0.0695	0.1186	-0.104	0.0377	-0.002	0.0253	-0.043	0.1032	-0.006	0.0862	0.3186	0.4400***
	Very late	0.0558	0.0181	0.0278	0.0169	0.0523	0.0965	-0.044	0.0591	0.0318	0.006	-0.019	0.0863	0.0013	0.0731	0.2184	0.4955***
Partial R ²	Timely	0.0143	0.1228	0.0255	-0.044	-0.072	-0.004	0.0366	0.0148	0.0079	-0.002	-0.005	0.1063	0.457	0.1334	0.1673	
	Late	0.0066	-0.001	-0.031	0.1044	-0.031	-0.002	-0.001	0.0054	0.0048	-0.002	-0.009	0.051	0.588	0.1743	0.1402	
	Very late	0.0033	-0.129	0.1487	0.0115	-0.005	0.0483	0.0011	-0.026	0.0014	-0.009	0.02	0.0897	0.3101	0.3976	0.1082	
RESIDUAL EFFECT	Timely	0.2038															
	Late	0.0544															
	Very late	0.1703															

Phenotypal Correlations

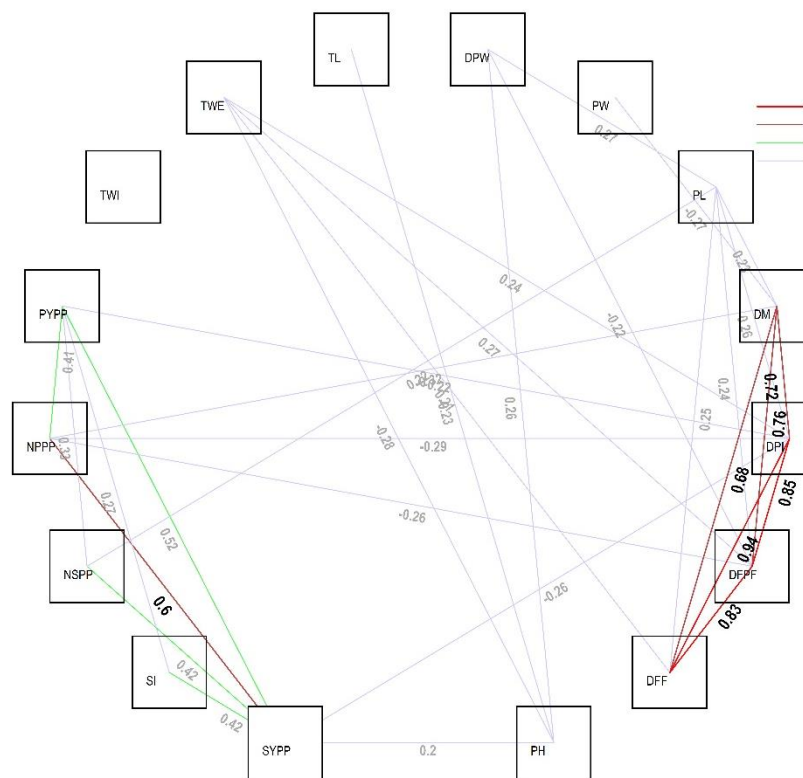


Fig. 4.1 Phenotypal correlation diagram for seed yield per plant in timely sown condition

Shaded Correlation Matrix

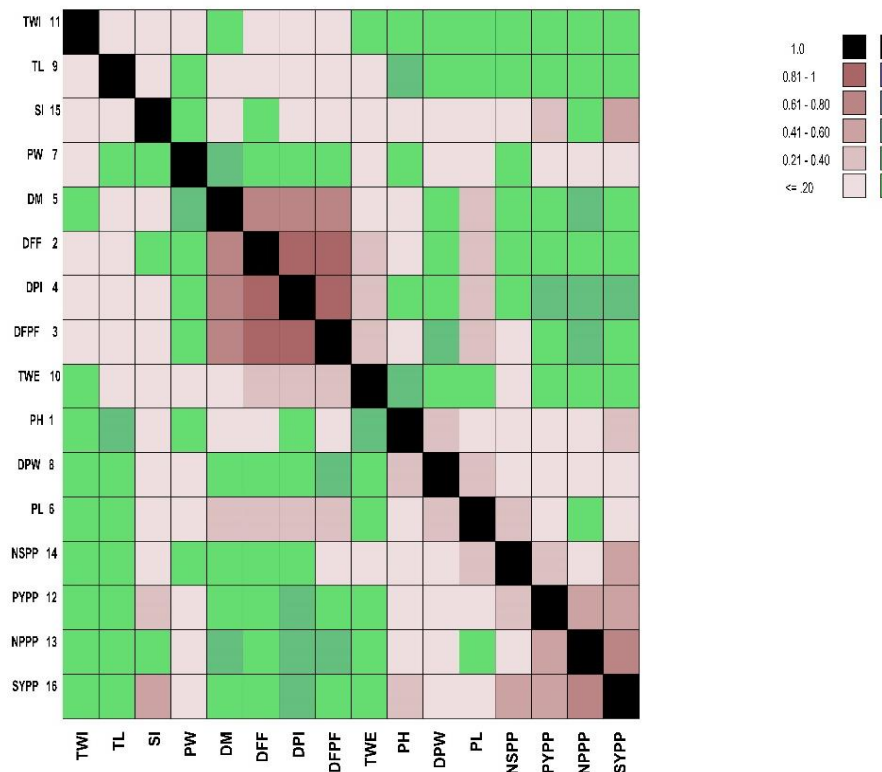


Fig. 4.2 shaded Phenotypal correlation matrix for seed yield per plant in timely sown condition

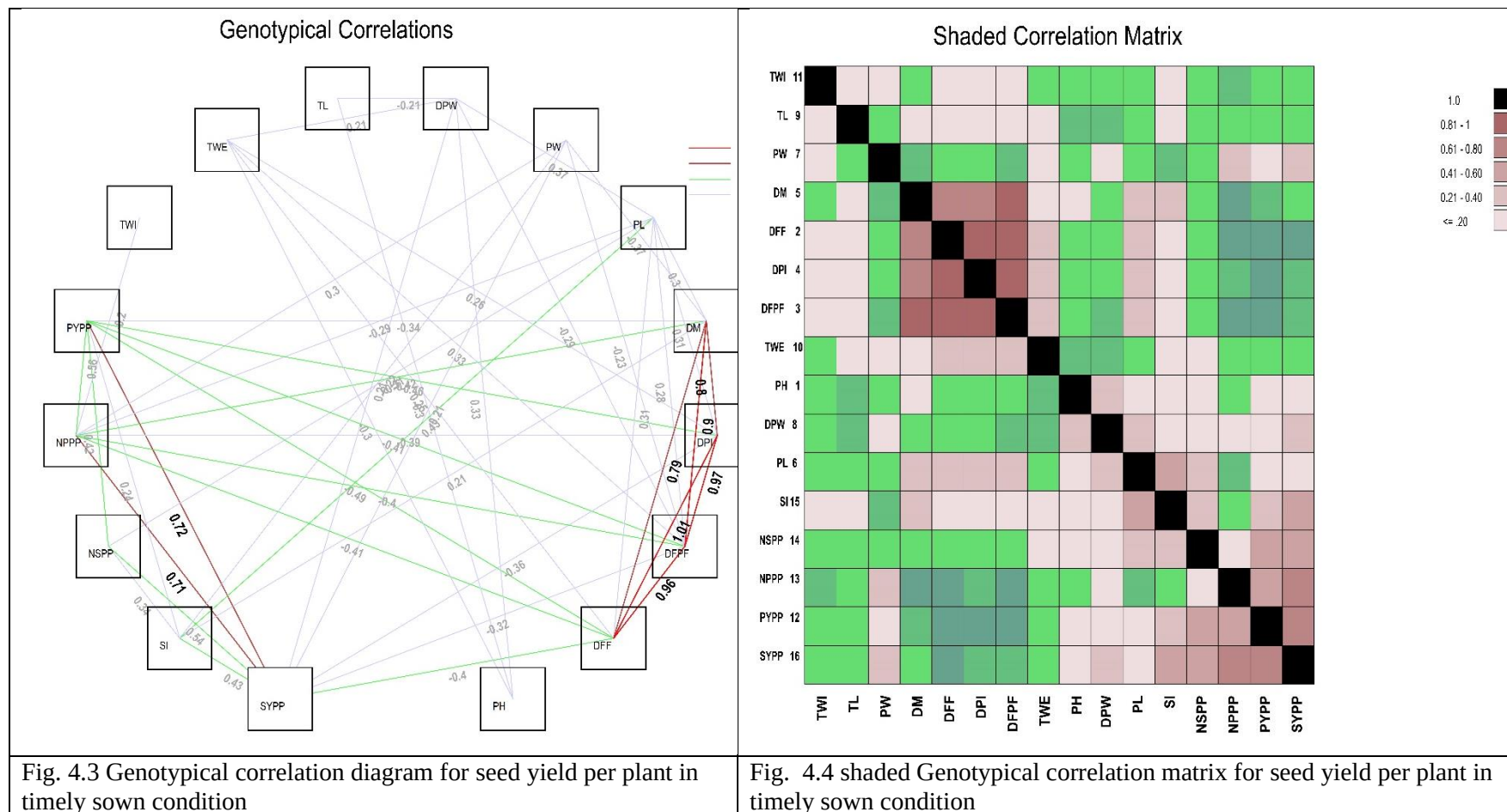


Fig. 4.3 Genotypical correlation diagram for seed yield per plant in timely sown condition

Fig. 4.4 shaded Genotypical correlation matrix for seed yield per plant in timely sown condition

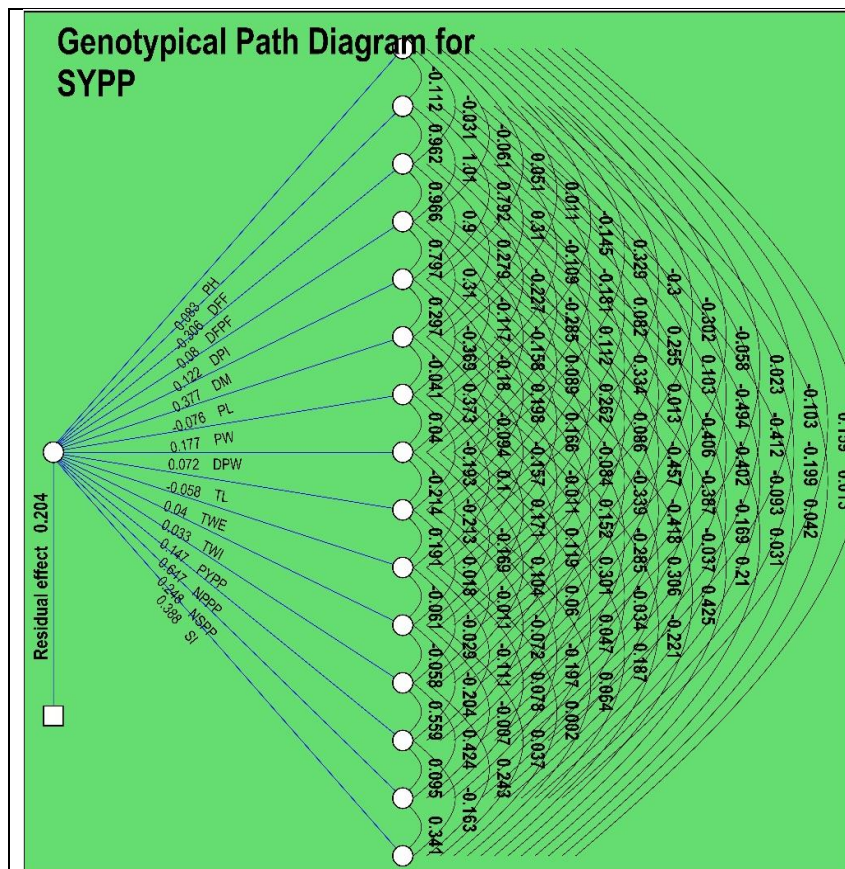


Fig. 4.5 Genotypical path diagram for seed yield per plant in timely sown condition

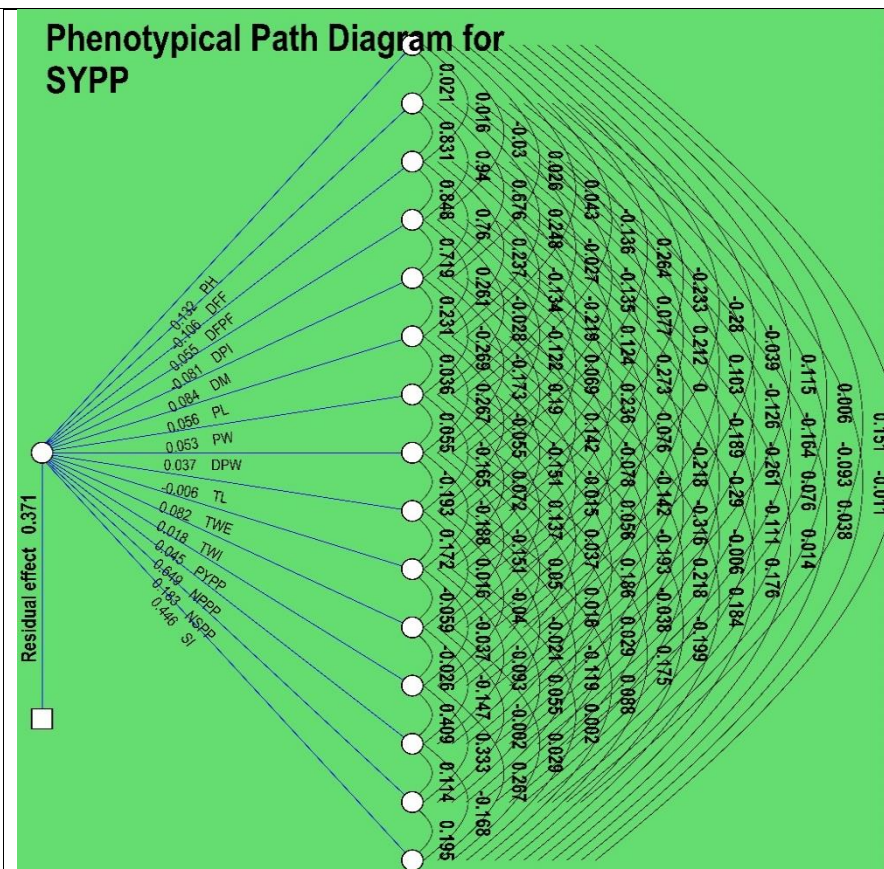
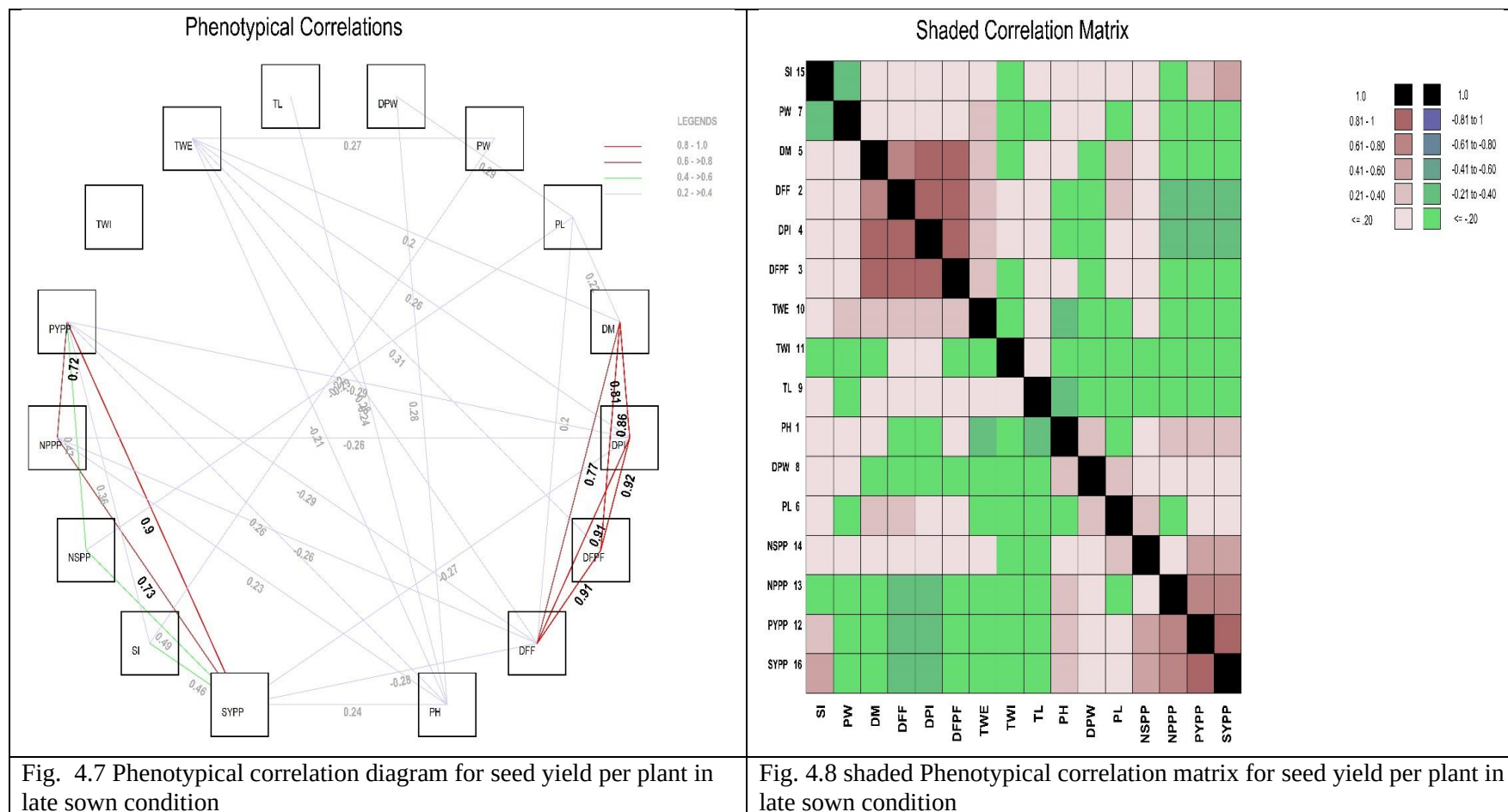
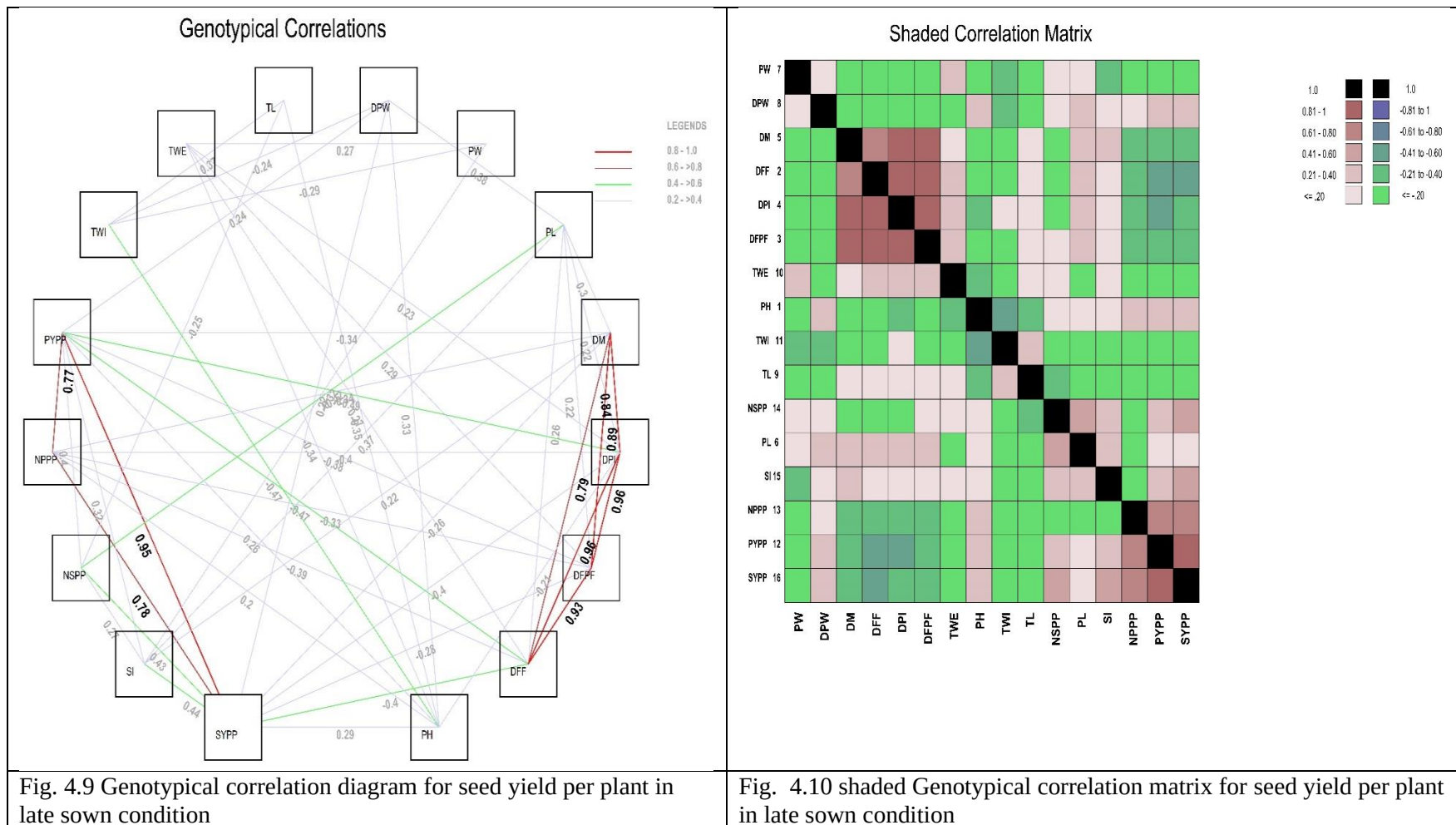


Fig. 4.6 Phenotypical path diagram for seed yield per plant in timely sown condition





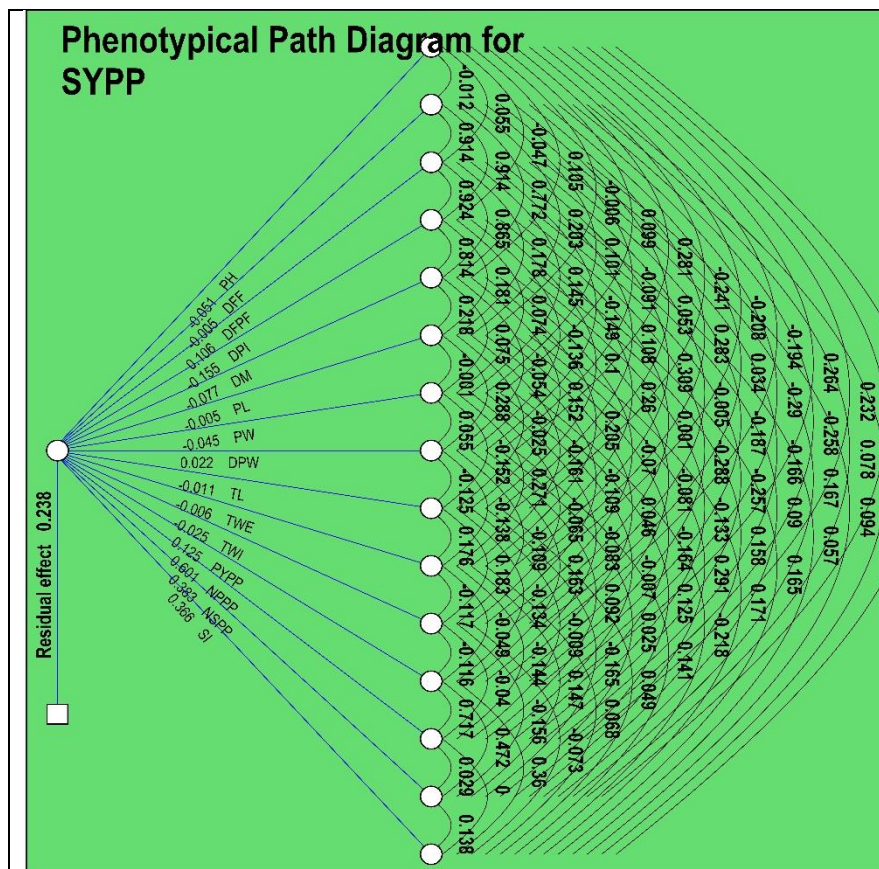


Fig. 4.11 Phenotypical path diagram for seed yield per plant in late sown condition

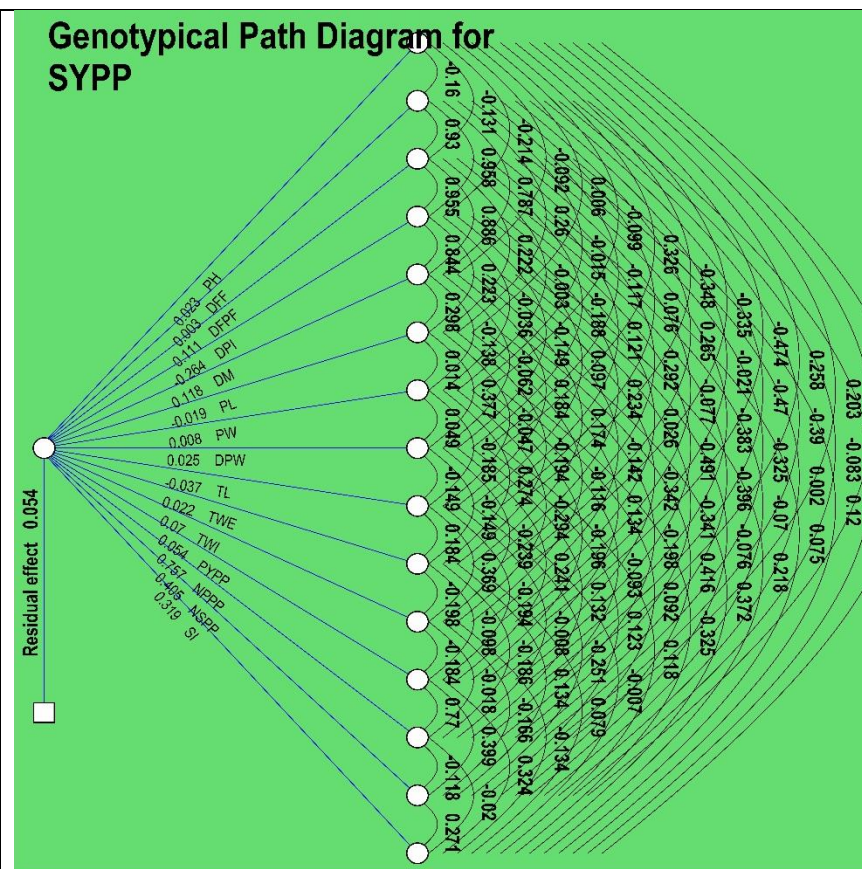
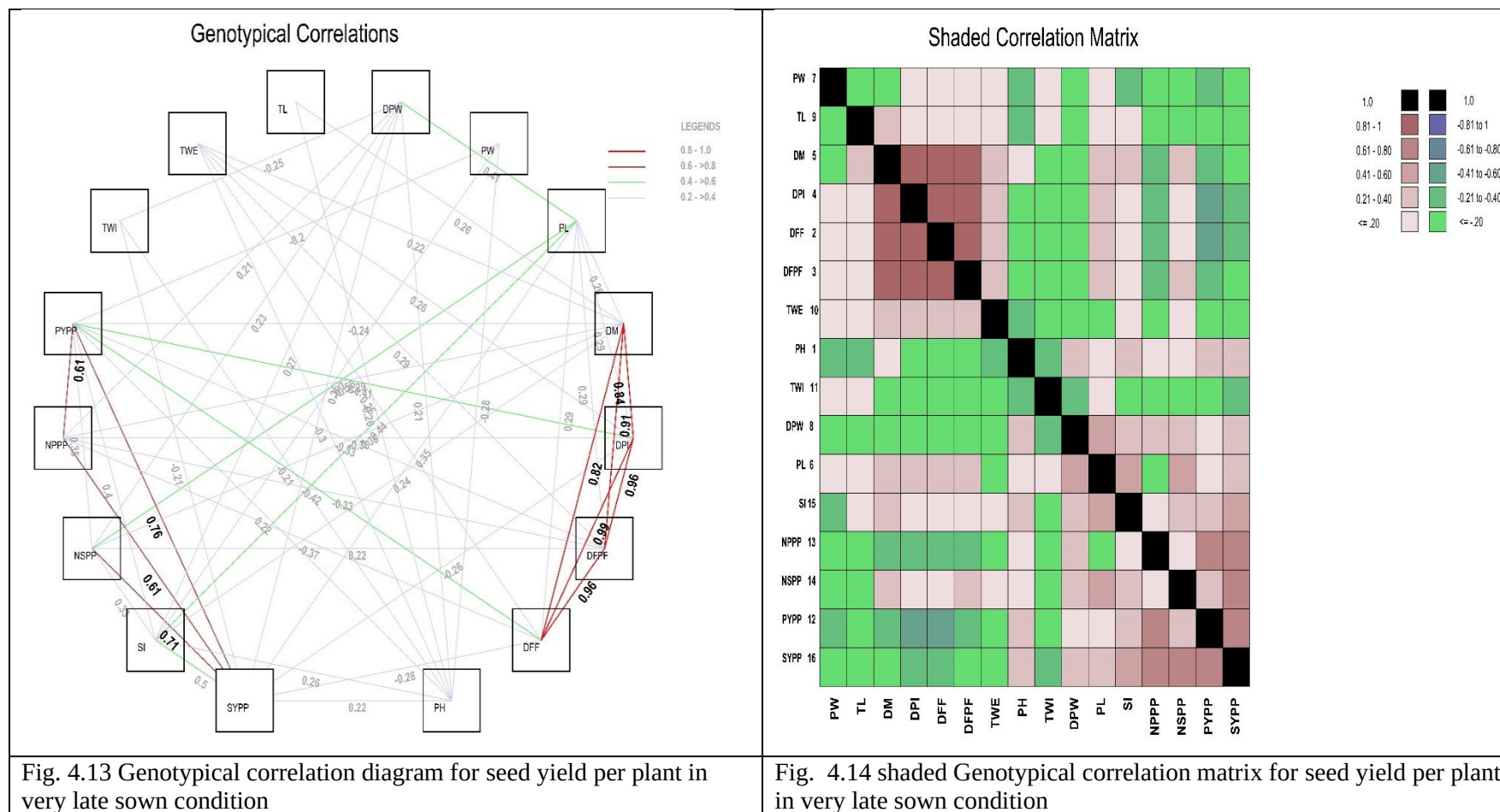
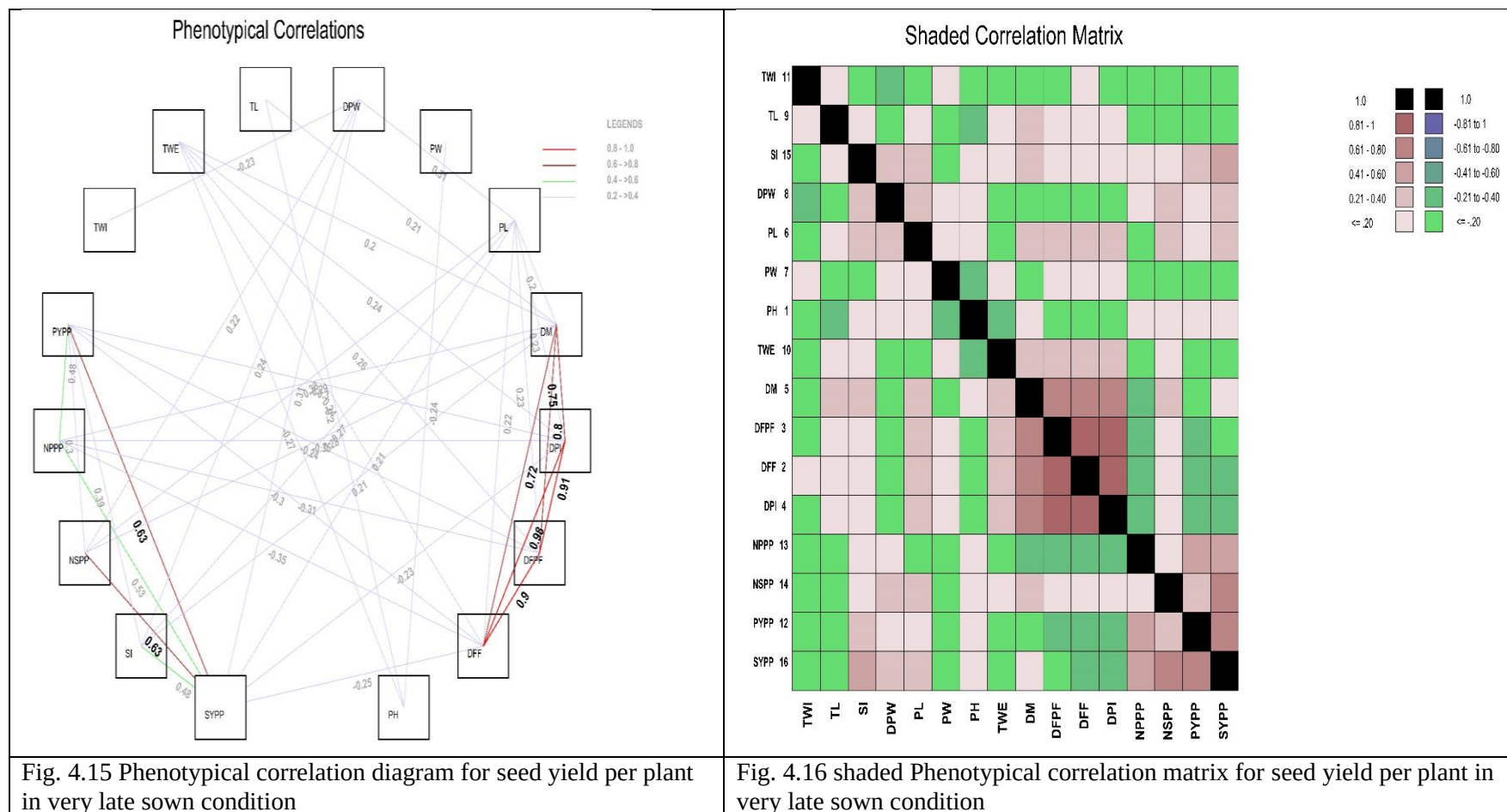


Fig. 4.12 Genotypical path diagram for seed yield per plant in late sown condition





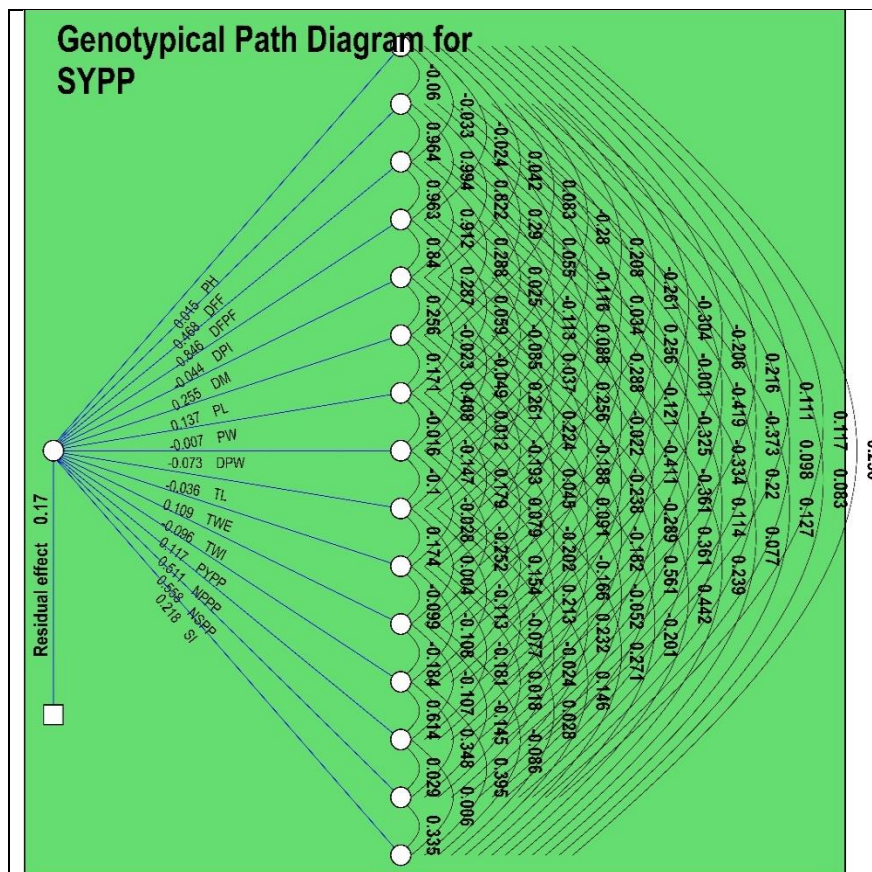


Fig. 4.17 Genotypical path diagram for seed yield per plant in very late sown condition

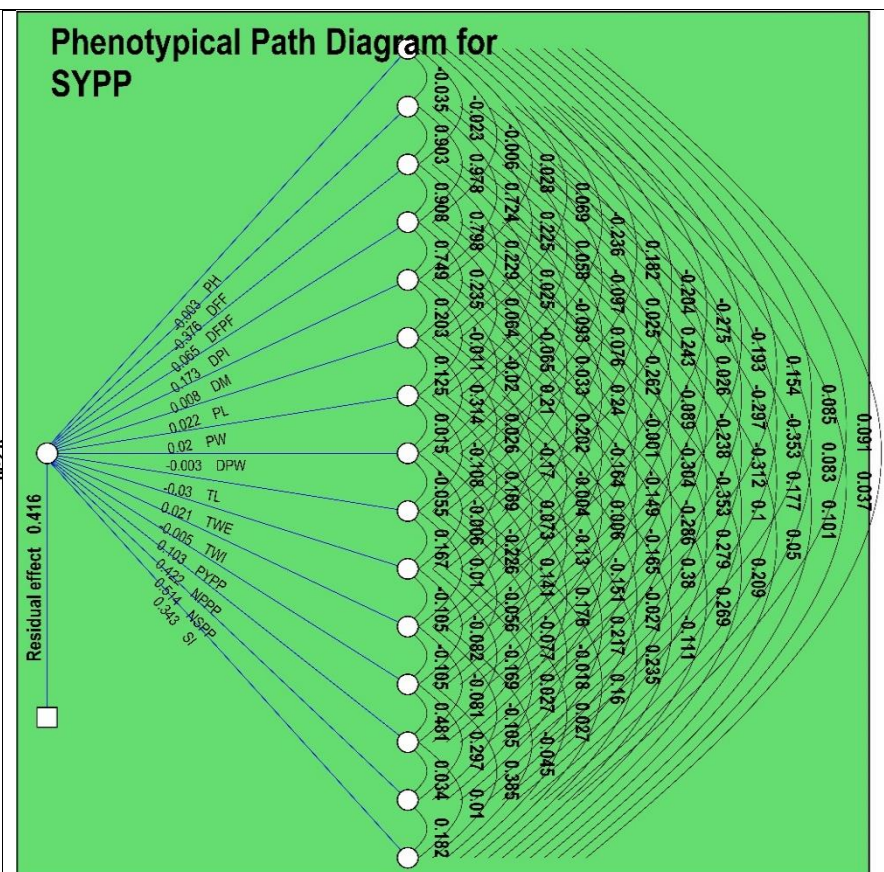


Fig. 4.18 Phenotypical path diagram for seed yield per plant in very late sown condition

4.5.2.14. Number of seeds per pod

Number of seeds per pod (table 4.5) exhibited significant and positive association with 100 seed weight (g) (0.341, 0.271 and 0.335) and seed yield per Plant (g) (0.539, 0.431 and 0.712) in all three conditions respectively.

4.5.2.15. 100 Seed Weight (g)

100 seed weight (g) (table 4.5) exhibited significant and positive association with seed yield per Plant (g) (0.431, 0.440 and 0.496) in all three conditions respectively.

4.6. Path Coefficient Analysis

The path analysis shows whether the association of characters with yield is due to its direct effect or is a consequence of their direct effects *via.*, other component characters on yield. In other words, it measures the cause of association between two or more variables. It is imperative that most of the characters contributing to yield are interrelated and are affected by each other. If a large number of characters are contributing to the final product *i.e.* yield and they are inter-related within themselves in a complex way, then it becomes difficult to sort out and evaluate such indirect association. One character influence is not apparent at first sight. Hence, all the correlations are partitioned into direct and indirect effects of character, alone as “Direct effect” and the fraction which is due to correlation of the character with the remaining characters, as “Indirect effect”.

In the present investigation, the phenotypic and genotypic correlation of seed yield with other quantitative characters are partitioned into their corresponding direct and indirect effect through path coefficient analysis. The obtained results have been presented in (Table 4.6) and (Table 4.7); (Fig. 4.2 to Fig 4.18).

4.6.1. Direct and indirect effect at phenotypic level

4.6.1.1. Direct effect with seed yield

Highest significant Positive direct effect has been observed in (Table 4.6) Plant height (0.1322) in timely condition, pod yield per plant (0.449), (0.1253) and (0.1035), and number of pod per plant (0.649), (0.6041) and (0.4218), days to 50% flowering (0.0548), (0.1057) and (0.0652) 100 Seed Weight (0.4464), (0.3664) and (0.3427) followed by number of seed per pod (0.1834), (0.3664) and (0.3427) in all three conditions, days to pod initiation (0.1734) in very late conditions and days to maturity (0.0839) in timely condition, pod length (0.1368) in very late condition, tuber weight (0.0822) (in timely) and pod width (0.0534) and (0.020) also in timely and very late condition. Tuber diameter (0.0184) in timely condition. Dry pod weight in timely and late condition (0.0373) and (0.0222) and lastly tuber weight in timey and very late conditions (0.082) and (0.0204).

Following showed significant negative direct association with Plant height in late and very late condition (-0.051) and (-0.003), Days to first flowering (-0.306), (-0.005) and (-0.376) (in timely, late and very late condition) *i.e.*, days to first flowering in late condition (-0.119), days to 50% flowering (-0.080) and (-0.846) in timely and late condition, days to pod initiation (-0.081) and (-0.155) in timely and late conditions, pod length (-0.076) and 0.019) in both timely and very late condition, days to maturity in timely (0.0839), in very late (-0.077) and late condition (0.2547), pod width (-0.022) in late condition, tuber length (-0.006), (-0.011) and (-0.03) in all three conditions, dry pod weight (-0.004) in very late condition and tuber weight (-0.005) in very late conditions. tuber length (-0.058), (-0.037) and (-0.036) in all three conditions. Tuber diameter in late and very late condition (-0.025) and (-0.005) and lastly tuber weight in late condition (-0.006).

4.6.1.2. Indirect effect

4.6.1.2.1. Seed yield per plant vs Plant height

Plant height (in Table 4.6) exhibits indirect effect high positive significant association with seed yield per plant (0.2027), (0.2365) and (0.1659) in all three conditions. Its positive association with seed yield is due to DPW (0.035) in timely condition DFPF (0.0022) in timely condition, DFF (0.0028), (0.0006) and (0.0001) in all three conditions, PL (0.0057) and (0.0003) in timely and late condition, DM (0.0035) in timely condition, DPI (0.0024) in late condition, TL (0.0123) and (0.0006) in timely and late conditions, TWE (0.0107) and (0.0008) in late and very late conditions, tuber diameter in late and very late conditions (0.0099) and (0.0006), PYPP (0.0151), NPPP (0.0008), NSPP (0.0199) and SI (0.0141) in timely condition.

While plant height exhibits low indirect effect nullified by negative indirect effect *via*. traits days to 50% flowering (-0.003) and pod width/PW (-0.0005) in late condition followed by days to pod initiation/DPI (-0.004) in timely condition, days to maturity/ DM in (-0.005) and (-0.004) in late and very condition, DPW/dry pod weight (-0.014) and (-0.004) in late and very late condition, TWE/ tuber weight (-0.037) in timely condition. Pod length (-0.007) in very late condition, Pod yield per plant/PYPP (-0.004), and NPPP/ number pods per plant (-0.012), and Number of seed per pod/NSPP (-0.008) in very late condition followed by tuber diameter/TDI (-0.005) in timely condition and lastly 100 seed weight (-0.006), and (-0.004) in late and very late conditions.

4.6.1.2.2. Seed yield per plant vs Days to first flowering

Days to First Flower (DFF) (in Table 4.6) shows Positive indirect effects: Significant association with seed yield: Timely condition (-0.1849), Late condition (-0.2779), Very late condition (-0.2546). Positive association due to: DM (0.0174) in Timely condition, (0.0013) in Late condition DPI (0.0363) in Very late condition TWI (0.0019) in Timely condition, PYPP (0.0134) in Timely condition, NSPP (0.0099) in Timely condition, SI (0.0011) in Timely condition.

While negative indirect effects are mainly due to PH (-0.106) in timely condition, DPI (-0.367) in Very late condition, PL (-0.072) in Timely condition, DM (-0.272) in Very late condition, PW (-0.084) in Very late condition, TWI (-0.002) in Late condition which nullifies the significance of the trait with the seed yield per plant, rest exhibits a mild effect on the seed yield.

4.6.1.2.3. Seed yield per plant vs Days to 50% flowering

Days to 50% Flowering (DFPF) (in Table 4.6) Positive indirect effects: Timely condition (-0.1636), Late condition (-0.1499), Very late condition (-0.1308). Positive association due to: days to first flowering (0.045), (0.096) and (0.058) in all three conditions, DPI (0.0465), (0.045), (0.096) in Timely, late and very late condition, Days to maturity (0.041), (0.091), (0.052) in Late condition, followed by number of pods per plant and 100 seed index which has very small influence on the association. While negative indirect effects: Plant height (-0.003) in Late condition followed by PW (-0.007) in early condition, PYPP/ pod yield per plant (0.0652) in Very late condition, dry pod weight in all three conditions, (-0.01), (-0.018), (-0.02).

4.6.1.2.4. Seed yield per plant vs Days to pod initiation

Days to pod initiation (in Table 4.6) exhibits significant negative association with seed yield per plant (-0.2610), (-0.2672) and (-0.2546) in all conditions due to negative indirect effect with tuber weight (-0.019), (0.014) and tuber length (-0.006), (-0.016) in timely and late condition followed by days to first flowering (-0.076), (-0.142), and days to 50% flowering (-0.069), (-0.144), days to maturity (-0.058), (-0.126), pod length (-0.021), (-0.028), also in timely and late condition.

While positive indirect effect due to plant height (0.002), (0.007), dry pod weight (0.009), (0.021), pod yield per plant (0.017), (0.044), no. of pod per plant (0.023), (0.039) in timely and late conditions. Lastly, tuber weight (0.041) and no. of seed per plant (0.017) in very late condition.

Days to pod initiation exhibits significant association with seed yield per plant (-0.3686), (-0.3956) and (-0.2589) shows positive indirect effect with days first flowering (0.1232) in timely condition, days to maturity (0.0972) and days to 50% flowering (0.1179) in timely condition, number of pods per plant in very late and late condition (0.104), (0.016) followed by Pod length (0.0378) in timely condition, Pod width (0.009) in late condition only, 100 Seed Weight (0.037) in timely conditions respectively, dry pod weight (0.045), (0.018) and (0.024) and tuber length (0.010) in timely conditions, tuber weight in timely and late conditions (0.010) and (0.001) and tuber weight in (0.031) in timely conditions.

While days to pod initiation exhibits negative indirect effect with plant height in timely and late conditions (-0.005) and (-0.020), days to first flowering (-0.076) and (-0.142) in timely and late condition, 100 Seed Weight (-0.02) and (0.003) in late and very late conditions days to 50% flowering (-0.231) and (-0.074) in timely and late condition, days to maturity (-0.058), (-0.021) and Pod length (-0.126) and (-0.028) in timely and late condition, pod weight in late and very late conditions (-0.002) and (-0.001), Pod yield per plant (-0.171), (-0.176) and (-0.151), number of pod per plant (-0.077), (-0.135) and (-0.135), number of seed per pod in late conditions (-0.002) tuber diameter (-0.004), in late condition.

4.6.1.2.5. Seed yield per plant vs Days to maturity

Days to maturity (in Table 4.6) exhibits only negative significant association with seed yield per plant (-0.133) in timely condition mainly due to pod width (-0.023), (-0.006), (-0.004) in all three conditions followed by days to first flowering, days to 50% flowering, days to pod initiation, pod length and tuber weight (-0.059), (-0.066), (-0.062), (-0.017), (-0.016) respectively in late condition followed by no. of pods per plant (-0.027), and dry pod weight (-0.015) both in timely condition.

While positive indirect effect by days to first flowering (0.0560, days to 50% flowering (0.063), days to pod initiation (0.060) and pod length (0.19) in timely condition. Rest of the traits show low indirect effect.

4.6.1.2.6. Seed yield per plant vs Pod length

Pod length (in Table 4.6) exhibits significant positive association with seed yield per plant in very late condition (0.216) is mainly due to positive indirect effect of no. of seed per pod (0.008), dry pod weight (0.006), days to 50% flowering (0.005), days to pod initiation (0.005), days to first flowering (0.005) and days to maturity (0.004) while it is nullified by negative indirect effect was mainly due to no. of pods/plant (-0.004) and tuber weight (-0.004).

4.6.1.2.7. Seed yield per plant vs Pod width

Pod width (in Table 4.6) exhibits no-significant association with seed yield per plant due to negative indirect effect of plant height (-0.005), (-0.005), days to maturity (-0.003), (-0.002) and number of seed per plant (-0.002), (-0.001) in late and very late condition. While its direct positive effect was nullified by negative indirect effect of plant height, days to first flowering, days to 50% flowering days to pod initiation and number of seeds per pod, *i.e.* (-0.007), (-0.007), (-0.002), (-0.004) and (-0.002) respectively.

4.6.1.2.8. Seed yield per plant vs Dry pod weight

Dry pod weight (in Table 4.6) exhibits significant positive association with seed yield per plant (0.1667), (0.155) and (0.306) in all three conditions due to positive indirect effect of plant height (0.009), (0.006), 100 seed weight (0.006), (0.003) and pod yield per plant (0.001), (0.003) in timely and late conditions followed by days to first flowering (0.003), days to 50% flowering (0.0003) and tuber diameter (0.0008) in very late conditions.

While the negative indirect effect was mainly due to days to 50% flowering (-0.008), (-0.003), tuber length (-0.007), (-0.003), tuber diameter (-0.006), (-0.002) in timely and late conditions and the remaining characters showed low indirect effect.

4.6.1.2.9. Seed yield per plant vs Tuber length

Tuber length (in Table 4.6) exhibits negative and non-significant association with seed yield per plant it is mainly due to negative indirect effect days to maturity (-0.002), (-0.002), (0.002) tuber weight (-0.001), (-0.001) and (-0.006) in all three conditions were nullified by positive indirect effect of (0.015), (0.002), (0.001) and pod yield per plant (0.001), 90.0017) and (0.0001) in all three conditions.

4.6.1.2.10. Seed yield per plant vs Tuber weight

Tuber weight (in Table 4.6) exhibits negative non-significant association with seed yield per plant with negative indirect effect of plant height (-0.023), (-0.06) in timely and very late con (-0.008) in timely and very late conditions. While positive indirect effect was shown in days to 505 flowering (0.022), days to pod initiation (0.019) and days to first flowering (0.017) all in timely condition.

4.6.1.2.11. Seed yield per plant vs Tuber diameter

Tuber diameter exhibits significant negative association with seed yield per plant (-0.135) and (-0.136) in late and very late condition which was mainly due to tuber length (-0.002) and days to first flowering (-0.001) in late condition followed by pod width (-0.002) and days to first flowering (0.001).

While it was nullified by positive indirect effect of (0.004), (0.001) plant height, number of seed per pod (0.003), (0.001) and pod yield per plant (0.002), 90.001) in late and very late conditions. While remaining occurred to be low indirect effect.

4.6.1.2.12. Seed yield per plant vs Pod yield per plant

Pod yield per plant (in Table 4.6) exhibits positive significant with seed yield per plant (0.518), (0.899), (0.630) in all three conditions which is mainly due to positive indirect effect with plant height in all there conditions (0.005), (0.033) and (0.015), dry pod weight (0.002), (0.020), (0.014), number of pods per plant (0.018), (0.089, (0.049), number of seed per pod (0.014), (0.059),

(0.030), and seed index/ 100 seed weight (0.0012), (0.045), (0.039) in all three conditions.

While the negative indirect effecting are days to first flowering (-0.006), (-0.036), (-0.031), days to 50% flowering (-0.009), (-0.023, (-0.025), days to pod initiation (-0.012), 9-0.036), (-0.032) in all three conditions.

4.6.1.2.13. Seed yield per plant vs Number of seed per pod

Number of seed per pod (in Table 4.6) exhibits positive significant on seed yield per plant (0.418), (0.492) and (0.630) which is mainly due to positive indirect effect with plant height (0.027), (0.058) and (0.046), days to 50% flowering (0.014), (0.064) and (0.090), pod length (0.04), (0.111) and (0.195), dry pod weight (0.005), (0.009) and (0.111), pod yield per plant (0.061), (0.181) and (0.152), 100 seed index (0.035), (0.052, (0.093), number of seed per plant, (0.021), (0.011) and (0.017), in all three conditions.

While it exhibits negative indirect effect due to day to first flowering (-0.017) and days to pod initiation (-0.02) in timely conditions followed by pod width (-0.14) and tuber diameter 9-0.0540 in very late condition.

While the negative indirect effect was found to be pod width (-0.089), (-0.080) and (-0.038)

4.6.1.2.14. Seed yield per plant vs Number of pod per plant

Number of pod per plant (in Table 4.6) exhibits positive significant association with seed yield per plant (0.603), (0.729) and (0.533) which is mainly due to positive indirect effect with plant height (0.004), (0.139) and (0.035), dry pod weight (0.010), (0.055) and (0.074), pod yield per plant (0.265), (0.430) and (0.202) and number of seed per pod (0.074), (0.017) and (0.004).

While negative indirect effect was due to days to first flowering (-0.106), (-0.155), (-0.149), days to 50% flowering (-0.17), (-0.1), (-0.131), days to pod initiation (-0.188), (-0.155), (-0.149) and pod length (-0.125), (-0.099) and (-0.069) in timely, late and very late condition.

4.6.1.2.15. Seed yield per plant vs 100 Seed Weight

100 Seed Weight/100 seed weight (g) (in Table 4.6) exhibits positive significant association with seed yield per plant (0.422), (0.459) and (0.481) in timely late and very late condition which is mainly due to positive indirect effect with plant height (0.047), (0.040), (0.065), days to 50% flowering (0.017), (0.034), (0.034), followed by days to maturity (0.078), (0.060), (0.071), pod length (0.082), (0.062), (0.092), dry pod weight (0.078), (0.051), (0.080), number of seed per plant, (0.087), (0.050) and (0.062), tuber length (0.039), (0.017), (0.054) and pod yield per plant (0.119), (0.131), (0.132), In all these conditions.

4.6.2. Direct and indirect effect at genotypic level

4.6.2.1. Direct effect

Highest significant Positive direct effect (in Table 4.7) has been observed in Days to first flowering (0.0031) (in timely condition) and (0.4680) in Very late condition, followed by pod yield per plant (0.1468), (0.0539) and (0.1174) Plant height (0.0827), (0.025) and (0.0149) and number of pod per plant (0.6467), (0.7567) and (0.5111), in all three conditions, days to 50% flowering (0.1114) in late condition, days to pod initiation (0.122) in timely conditions and days to maturity in timely (0.3769), in late (0.1177) and late condition (0.2547), pod length (0.1368) in very late condition, 100 Seed Weight (0.3879), (0.3186) and (0.2184) followed by number of seed per pod (0.2471), (0.4045) and (0.5583) in timely, late and very late condition, tuber weight (0.0390), (0.0210) and (0.1086) (in timely, late and very late condition) and lastly pod width (0.1765) and (0.0225) also in timely and late condition. Tuber diameter in late condition (0.701) and 0.0325 in timely condition. Dry pod weight in timely and late condition (0.035) and (0.0701).

Following showed significant negative direct association with Days to first flowering (-0.306) (in timely condition) *i.e.*, days to first flowering in late condition (-0.119) days to 50% flowering (-0.080) and (-0.846) in timely and

late condition, days to pod initiation (-0.264) and (-0.044) in late and very late conditions days to maturity in very late condition (-0.050), pod length (-0.076) and 0.019) in both timely and very late condition, pod width (-0.099), (-0.060) and (-0.022), number of seed per pod (-0.006) in timely condition, dry pod weight (-0.303), (-0.131) and (-0.303) and tuber weight (-0.005) in very late conditions. tuber length (-0.058), (-0.037) and (-0.036) in all three conditions.

4.6.2.2. Indirect effect

4.6.2.2.1. Seed yield per plant vs Plant height

Plant height (in Table 4.7) exhibits positive significant association with seed yield per plant late and very late condition (0.293), (0.224) which is mainly due to positive indirect effect high due to dry pod weight (0.027), (0.007), (0.003) pod yield per plant(0.001), (0.005),(0.003), number of seed per plant (0.013), (0.002), (0.001), 100 seed index (0.013), (0.003), (0.003)and pod length (0.001, (0.001) and (0.001) in timely late and very late condition.

While negative indirect effect nullifies *i.e.* pod width (-0.012), (-0.002), (-0.004), tuber width (-0.005), (-0.011), (-0.003), tuber length (-0.025), (-0.008), (-0.04) and tuber weight (-0.025), (-0.008) and (-0.005).

4.6.2.2.2. Seed yield per plant vs Days to first flowering

Days to First Flowering (in Table 4.7) (DFF) shows negatively Significant association with seed yield: Timely condition (-0.400), Late condition (-0.401), Very late condition (-0.275). Positive association due to negative indirect effect of Days to 50% flowering (-0.295), days to pod initiation (-0.309), days to maturity (-0.243) in Timely condition followed by pod yield per plant (-0.002), (-0.196) and number of pod per plant (-0.001), (-0.175) in late and very late conditions.

While positive indirect effect has been found in days to 50 % flowering (0.451), days to pod initiation (0.465) and days to maturity (0.384) in very late condition.

4.6.2.2.3. Seed yield per plant vs Days to 50% flowering

Days to 50% Flowering (DFPF) (in Table 4.7) showed negative association with seed yield per plant: Timely condition (-0.320) and Late condition (-0.276) which is due to negative indirect effect of days to first flowering (-0.077) and (-0.815), DPI/days to pod initiation (-0.077) and (-0.815), in Timely late and very late condition, Days to maturity (-0.072), (-0.771), pod length (-0.022), (-0.244), tuber weight (-0.027), (-0.244) in timely and very Late condition, followed by plant height (-0.015), dry pod weight (-0.021), pod yield per plant (-0.043), number of pod per plant (-0.036) in late condition.

While in the positive indirect effect tuber diameter (0.102), pod yield per plant (0.274), number of pod per plant (0.282) in very late condition.

4.6.2.2.4. Seed yield per plant vs Days to pod initiation

Days to pod initiation (in Table 4.7) exhibits significant negative association with seed yield per plant (-0.363), (-0.395) and (-0.258) in all conditions due to negative indirect effect with tuber weight (-0.062), (0.011) and tuber length (-0.026), (-0.002) in late and very late condition followed by days to first flowering (-0.253), (-0.044), and days to 50% flowering (-0.252), (-0.043), days to maturity (-0.223), (-0.037), pod length (-0.059), (-0.013), also in late and very late condition. Plant height (-0.007), dry pod weight (-0.019), pod yield per plant (-0.056), number of pods per plant (-0.047) and number of seed per pod (-0.021) in timely condition.

While positive indirect effect is shown by pod yield per plant (0.129), (0.018) and number of pod per plant (0.104, 0.016) in late and very late condition followed by days to first flowering (0.123) and days to 50 % flowering (0.117) timely condition.

4.6.2.2.5. Seed yield per plant vs Days to maturity

Days to maturity (in Table 4.7) exhibits negative significant association with seed yield per plant (-0.191), (-0.264) in timely and late condition mainly due to negative indirect effect by pod width (-0.139), (-0.016), (-0.006), dry pod

weight (-0.068), (-0.007), (-0.13), tuber width (-0.032), (-0.07), (-0.048) pod yield per plant (-0.128), (-0.04), (-0.061), number of pod per plant (-0.157), (-0.04), (-0.074) in all three conditions.

While positive indirect effect by days to first flowering (0.298), (0.092), (0.209), days to 50% flowering (0.339), (0.104, (0.232), days to pod initiation (0.300) (0.099), (0.213 and pod length (0.112), (0.035), (0.065) in all three conditions. Remaining of the traits show low indirect effect.

4.6.2.2.6. Seed yield per plant vs Pod length

Pod length (in Table 4.7) exhibits significant positive association with seed yield per plant (0.126), (0.353) in late and very late conditions which is mainly due to tuber length (0.007), (0.001), (0.001) and tuber diameter (0.001), (0.002), (0.006) in all three conditions. While no. of seeds per pod (0.076), 100 seed weight (0.060), dry pod weight (0.055), days to pod initiation (0.039), days to 50% flowering (0.039) and days to first flowering (0.040) in very late condition.

While negative indirect effects tuber length (-0.034), (-0.001), 100 seed weight (-0.039), (-0.003) and days to first flowering (-0.04), (-0.005) in timely and late conditions. Remaining of the traits show low indirect effect.

4.6.2.2.7. Seed yield per plant vs Pod width

Pod width (in Table 4.7) exhibits positive significant association with seed yield per plant (0.207) in timely condition Which is mainly due to dry pod weight (0.007), tuber weight (0.017), tuber diameter (0.030), pod yield per plant (0.021) and no of pod per plant (0.053).

Pod width exhibits negative significant association (-0.155), (-0.154) with seed yield per plant in late and very late conditions mainly due to days to first flowering (-0.019), (-0.004), (-0.004) and days to pod initiation (-0.021), (-0.004), (-0.004) in all three conditions followed by tuber diameter (-0.002), (-0.004) in late and very late conditions and 100 seed weight (-0.039), (-0.003) and plant height (-0.026), (-0.004) in timely and late conditions.

4.6.2.2.8. Seed yield per plant vs Dry pod weight

Dry pod weight (in Table 4.7) exhibits positive significant association with seed yield per plant (0.205), (0.221) and (0.358) in all three conditions due to positive indirect effect of pod width (0.002), (0.001), (0.001) in all three conditions followed by tuber length (0.007), tuber diameter (0.018), days to first flowering (0.008), days to 50% flowering (0.008) and days to pod initiation (0.006) in very late condition. Lastly pod length (0.026), (0.009) and plant height (0.023), (0.008) in timely and late condition.

While negative indirect effect due to days to first flowering (-0.013), (-0.003), days to 50% flowering (-0.021), (-0.005), days to pod initiation (-0.011), (-0.004) and tuber length (-0.015), (-0.004) and the remaining characters showed low indirect effect.

4.6.2.2.9. Seed yield per plant vs Tuber length

Tuber length (in Table 4.7) exhibits negative significant association with seed yield per plant (-0.136), (-0.129) in timely and late conditions mainly due to negative indirect effect with days to first flowering (-0.005), (-0.003), (-0.001), days to 50% flowering (-0.007), (-0.005), (-0.003), days to pod initiation (-0.005), (-0.004), (-0.001), days to maturity (-0.011), (-0.007), (-0.009) and tuber weight (-0.011), (-0.007), (-0.006) in all three conditions.

While positive indirect effect due to pod width (0.011), (0.006), (0.005), dry pod weight (0.012), (0.005), (0.003) and no. of seed per plant (0.011), (0.010), (0.001) in all three conditions.

4.6.2.2.10. Seed yield per plant vs Tuber weight

Tuber weight (in Table 4.7) exhibits negative non-significant association with seed yield per plant with negative indirect effect of plant height (-0.012), (-0.07) (0.019), pod length (-0.06), (-0.021) in timely, late and very late condition dry pod weight (-0.009) (-0.003), (-0.003) and number of pods per plant, (-0.004), (-0.004), (-0.020) in timely, late and very late conditions.

While positive indirect effect was shown in days to first flowering (0.0003), (0.058), (0.0279) in all three conditions, days to 50% flowering (0.013), (0.006), (0.013, days to pod initiation (0.010), (0.005), (0.027) and days to maturity (0.006), (0.003), (0.024) all in timely condition.

4.6.2.2.11. Seed yield per plant vs Tuber diameter

Tuber diameter (in Table 4.7) exhibits significant negative association with seed yield per plant (-0.1383) and (-0.1298) in timely and late condition which was mainly due to plant height (-0.002), (0.033), days to maturity (-0.003), (-0.09) dry pod weight (-0.006), (-0.017), tuber weight (-0.002), (-0.014) in timely and late condition followed by days to pod initiation (0.002), (0.001) , tuber length (0.001), (0.025) in timely and late conditions.

Which is nullified by positive indirect effect of days to pod initiation in timely and late conditions (0.002) and (0.001) followed by plant height (0.0190, days to 50% flowering (0.011), days to maturity (0.002), days to pod initiation (0.002), dry pod weight (0.024), pod yield per plant (0.017), number of seed per plant (0.013) and number of pods per plant (0.010) in very late condition).

4.6.2.2.12. Seed yield per plant vs Days to pod initiation

Days to pod initiation (in Table 4.7) exhibits significant negative association with seed yield per plant (-0.369), (-0.396) and (-0.259) mainly due to positive indirect effect with days first flowering (0.123) in timely condition, days to maturity(0.097) and days to 50% flowering (0.118) in timely condition, number of pods per plant in very late and late condition (0.104), (0.016) followed by pod length (0.0378) in timely condition, Pod width (0.009) in late condition only, 100 Seed Weight (0.037) in timely conditions respectively, dry pod weight (0.045), (0.018) and (0.024) and tuber length (0.010) in timely conditions, tuber weight in timely and late conditions (0.010) and (0.001) and tuber weight in (0.031) in timely conditions.

While days to pod initiation exhibits negative indirect effect with plant height in timely and late conditions (-0.005) and (-0.020), days to first flowering

(-0.076) and (-0.142) in timely and late condition, 100 Seed Weight (-0.02) and (0.003) in late and very late conditions days to 50% flowering (-0.231) and (-0.074) in timely and late condition, days to maturity (-0.058), (-0.021) and Pod length (-0.126) and (-0.028) in timely and late condition, pod weight in late and very late conditions (-0.002) and (-0.001), Pod yield per plant (-0.171), (-0.176) and (-0.151), number of pod per plant (-0.077), (-0.135) and (-0.135), number of seed per pod in late conditions (-0.002) tuber diameter (-0.004), in late condition.

4.6.2.2.13. Seed yield per plant vs Pod yield per plant

Pod yield per plant (in Table 4.7) exhibits positive significant with seed yield per plant (0.724), (0.946), (0.764) in all three conditions which is mainly due to positive indirect effect with pod length (0.022), (0.007), (0.010), plant height (0.003), (0.013), (0.025), dry pod weight (0.015), (0.013), (0.018), no. pod per plant (0.082), (0.041), (0.072), no. of seed per pod (0.062), (0.021), (0.040) and 100 seed weight (0.035), (0.017), (0.046) in all three conditions. While negative indirect effect with days to first flowering (-0.073), (-0.025), (-0.049), days to 50% flowering (-0.06), (-0.021), (-0.038), days to pod initiation (-0.067), (-0.026), (-0.048) and days to maturity (-0.05), (-0.018), (-0.028) in all three conditions.

4.6.2.2.14. Seed yield per plant vs Number of seed per pod

Number of seed per pod (in Table 4.7) exhibits positive significant association with seed yield per plant (0.538), (0.430) and (0.712) which is mainly due to positive indirect effect with plant height (0.039), (0.040) and (0.065), pod length (0.075), (0.168), (0.313) dry pod weight (0.011), (0.049) and (0.129), pod yield per plant (0.105), (0.161) and (0.194) and 100 seed weight (0.084), (0.109) and (0.108) in all three conditions.

While negative indirect effect was due to tuber length (-0.049), (-0.102), (0.014) and tuber diameter (-0.002), (-0.067), (-0.081) in all three conditions.

4.6.2.2.15. Seed yield per plant vs 100 Seed Weight

100 Seed Weight/100 seed weight (g) (in Table 4.7) exhibits positive significant association with seed yield per plant (0.431), (0.440) and (0.495) in timely late and very late condition which is mainly due to positive indirect effect with plant height (0.064), (0.053), (0.055), days to 50% flowering (0.016), (0.038), (0.027), days to first flowering (0.005), (0.016, (0.018), , days to pod initiation (0.011), (0.023), (0.016), followed by days to maturity (0.081), (0.069), (0.052), pod length (0.165), (0.118), (0.096), dry pod weight (0.072), (0.037), (0.059), tuber weight (0.0006, (0.025), (0.006), number of seed per pod (0.132), (0.086) and (0.073), tuber length (0.039), (0.017), (0.054) and pod yield per plant (0.094), (0.103), (0.86), In all these conditions

While the negative indirect effect was found to be pod width (-0.086), (-0.080) and (-0.0384 (-0.044) in all three condition and tuber diameter (-0.043), (-0.019) in late and very late condition, and lastly number of pods per plant (-0.063), (-0.006) in timely and late condition.

4.7. Estimation of genetic divergence

4.7.1. Morphological Divergence

To have an idea about the extent of similarity and differences present in the winged bean genotypes, cluster analysis of genotypes was performed. Genotypes were grouped into different clusters based on Tocher method by K. D. Tocher (Rao, 1952). The analysis of genetic divergence was used:

- a) To measure the genetic distance between genotypes;
- b) To relate clustering pattern with geographical origin,
- c) To identify promising genotypes for the initiation of crossing programme.

The distribution pattern of genotypes, their intra and inter-cluster distances, (D^2) value, cluster mean of different clusters and contribution percentage by the traits towards genetic divergence under recommended date of sowing (pooled E₁ and E₄), (pooled E₂ and E₅) and (pooled E₃ and E₆), are presented in the table 4.8, 4.9, 4.10, 4.11 and 4.12 respectively.

4.7.2. Group Constellations

As method suggested by Tocher (Rao, 1952), the genotypes was grouped into five clusters using estimated D^2 values as the square of the generalized distance. forty genotypes of winged bean which differed significantly with regard to the characters under studies display remarkable divergence and were grouped into five clusters following Mahalanobis's D^2 method (Table 4.9, Fig. 4.19 and Fig. 4.20. The genotypes present within cluster were closer to each than the genotypes in different clusters.

Table 4.8: Diverse winged bean promising genotypes for sixteen quantitative traits by Tocher's method.

S. No.	Characters	Range	Cluster
1	PH	Tall	III
		Dwarf	V
2	DFF	Early	II
		Late	III
3	DFPF	Early	II
		Late	III
4	DPI	Early	II
		Late	III
5	DM	Early	II
		Late	IV
6	PL	Long	III
		Short	V
7	PW	Long	V
		Short	I
8	DPW	High	III
		Low	II
9	TL	Long	V
		Short	II
10	TW	Long	V
		Short	III
11	TDI	Large	IV
		Small	III
12	PYPP	High	II
		Low	V
13	NPPP	High	II
		Low	IV
14	NSPP	High	III
		Low	I
15	SI	High	IV
		Low	V
16	SYPP	High	II
		Low	IV

Table 4.9: Composition of genotypes in five clusters in Winged bean

Cluster number	Number of genotypes	Name of genotypes
Cluster-1	33	Local wokha-2, Local Suchonoma, NUWB-4, Local peren, Local Medziphema, VRWB-23, VRWB-24, NUWB-3, VRWB-26, VRWB-68, VRWB-35, VRWB-36, LOCAL PANGTI-1, Local dimapur-1, VRWB-45, Local dimapur-2, Local akuk, VRWB-50, VRWB-54, Local wokha-1, VRWB-75, VRWB-77, VRBW-85, VRWB-88, Local baghty, VRWB-93, VRWB-100, VRWB-104, Local Mongsenyimti, VRWB-112, VRWB-115, VRWB-116, NUWB-2
Cluster -2	3	VRWB-17, VRWB-20, VRWB-27
Cluster -3	1	Local dimapur-3
Cluster -4	1	Local pangti-2
Cluster -5	2	VRWB-32, VRWB-59

Among five clusters, cluster-I was the largest one with 33 genotypes namely, Local wokha-2, Local Suchonoma, NUWB-4, Local peren, Local Medziphema, VRWB-23, VRWB-24, NUWB-3, VRWB-26, VRWB-68, VRWB-35, VRWB-36, LOCAL PANGTI-1, Local dimapur-1, VRWB-45, Local dimapur-2, Local akuk, VRWB-50, VRWB-54, Local wokha-1, VRWB-75, VRWB-77, VRBW-85, VRWB-88, Local baghty, VRWB-93, VRWB-100, VRWB-104, Local Mongsenyimti, VRWB-112, VRWB-115, VRWB-116 and NUWB-2. Whereas, cluster-V includes 2 genotypes namely VRWB-59, VRWB-32. followed by cluster II with 3 genotypes namely VRWB-17, Local Peren, VRWB-20 and VRWB-27. Followed by the cluster III and Cluster IV exhibits solo clusters or monogenic clusters with local attributes *i.e.*, genotypes namely Local Dimapur-3 and Local Pangti-2.

4.7.3. Average intra and inter cluster distances:

D^2 values of intra and inter-cluster distance are given in Table 4.10 and in Fig 4.20. The average D^2 values of intra and inter-clusters are given in Table 4.10. The

results showed that cluster V had maximum intra cluster D^2 value (9.89) which comprises two genotypes showed the highest genetic diversity among the genotypes within cluster with D^2 value 9.89 followed by cluster I with thirty-three genotypes with D^2 value 7.03 and Cluster II with three genotypes with D^2 value 3.5. The mono-genotypic clusters were represented by one genotype so the intra-cluster distance was found to be zero. Between clusters, inter-cluster distances varied from 42.24 to 10.8. Maximum inter-cluster distance (42.24) was observed between cluster-II and V followed by between cluster-III and V (42.09), cluster-II and IV (30.36), cluster-V and I (27.08), cluster-V and IV (22.89) cluster-III and IV (17.93), cluster-II and III (16.95), cluster-II and I (13.96) cluster-I and IV (12.88) and the least cluster distance between cluster-I and III (10.8).

4.7.4. Cluster mean for different characters:

A comparison of the cluster means values for sixteen traits in five different clusters reflected considerable differences present in them (Table 4.11). The cluster mean values showed a wide range of variations for all the characters undertaken in this study. Cluster-II accommodated 3 genotypes, which had maximum number of traits with lowest cluster mean value for days to first flowering (60.56), Day to 50% flowering (87.86), Day to pod initiation (64.04), days to pod initiation (125.64), days to maturity (144.85) which is a desirable character according to its earliness and also recorded least cluster mean was of dry pod weight (4.82) and tuber length (17.22), highest cluster mean value for number of seed per pod (41.28), Pod yield per plant (239.15) and seed yield per plant (134.83) followed by Cluster-III which comprises of one genotype shows highest cluster mean for Plant height (7.34), dry pod weight (7.57), number of seed per pod (12.77) and pod length (22.12), this also contributes highest cluster mean for days to first flowering (124.62), Day to 50% flowering (150.33), Day to pod initiation (128.34), this cluster also reflected lowest cluster mean value for tuber weight (25.24) and tuber width (1.96). Cluster-I which accommodated thirty-three genotypes which had no highest cluster mean value but shows low for number of seed per pod (11.46) and pods per plant. Cluster-V which accommodated two genotypes had maximum cluster mean value for pod width (2.89), tuber length (26.82) and tuber weight (103.03).

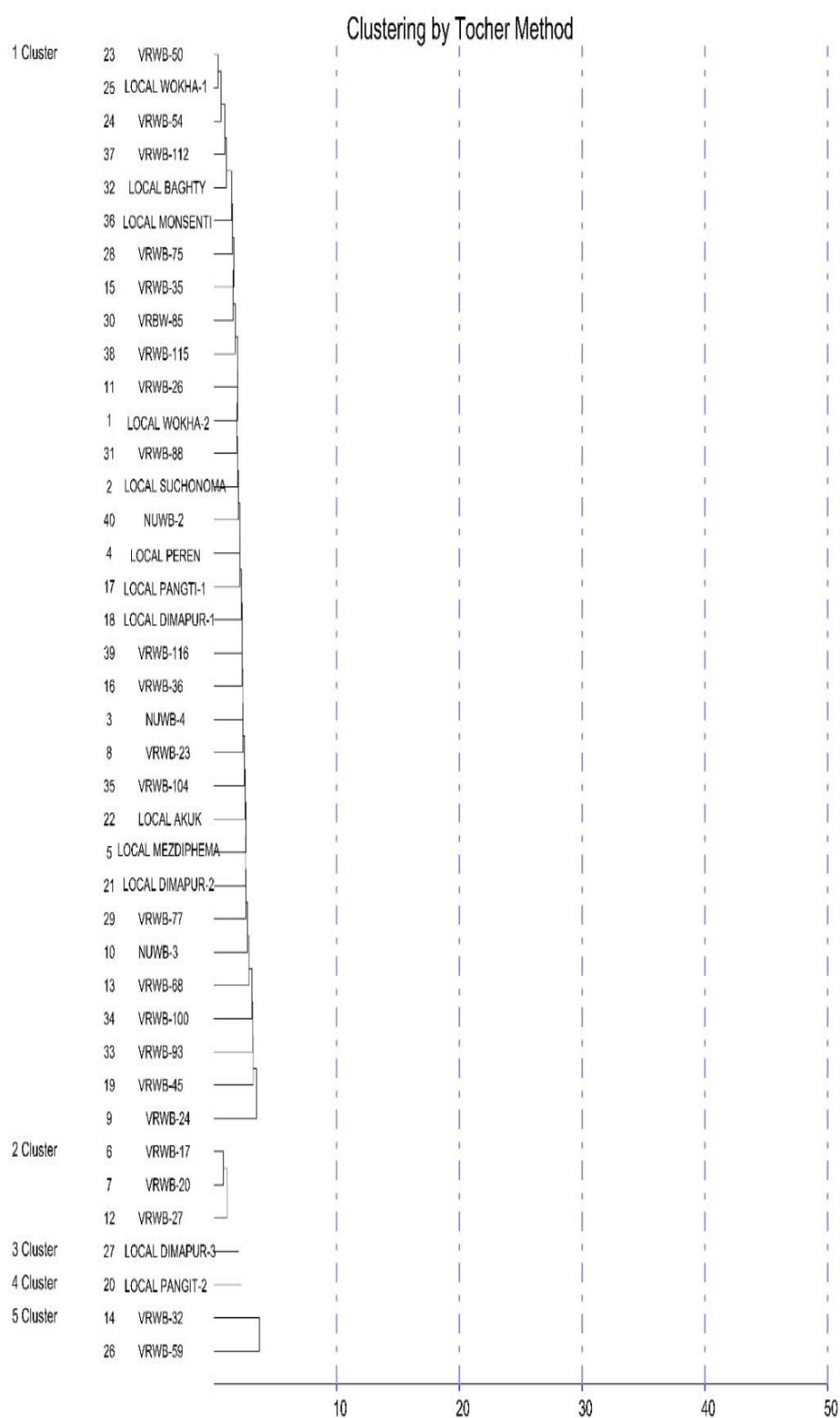


Fig. 4.19. Clustering of forty genotypes into five clusters using Tochers' method.

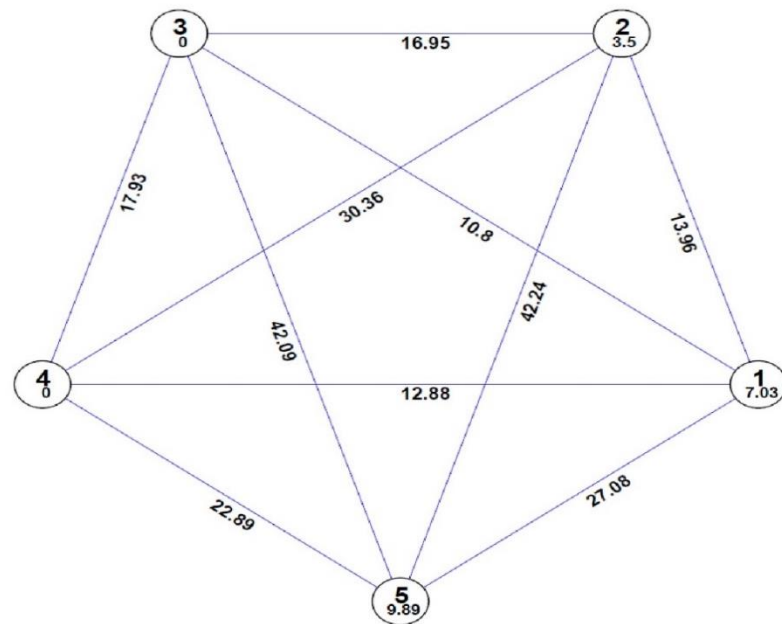


Fig. 4.20. Pictorial depiction of inter and intra cluster distance.

Table 4.10: Intra and Inter cluster distance of clusters in Winged bean

Clusters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Cluster 1	7.03	13.96	10.8	12.88	27.08
Cluster 2		3.5	16.95	30.36	42.24
Cluster 3			0	17.93	42.09
Cluster 4				0	22.89
Cluster 5					9.89

Table 4.11: Cluster means for sixteen characters for Winged bean

Characters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Plant height(m)	5.78	6.79	7.34	4.74	4.60
Days to first Flowering	95.65	60.56	124.69	122.18	102.55
Days to 50% Flowering	126.95	87.86	150.33	146.02	133.78
Days to Pod initiation	100.45	64.04	128.34	124.96	107.42
Days to Maturity	183.38	144.85	194.78	199.89	184.59
Pod Length(cm)	16.30	16.28	22.12	19.39	14.69
Pod Width(cm)	2.63	2.64	2.70	2.63	2.89
Dry pod weight (g)	4.82	6.00	7.57	5.35	5.25
Tuber length (cm)	25.24	17.22	24.92	22.48	26.82
Tuber weight (g)	39.21	33.58	25.84	50.11	103.03
Tuber Width (cm)	2.44	2.34	1.96	4.15	2.20
Pod Yield/plant	161.95	239.15	219.17	123.06	162.26
Number of pods/plant	32.13	41.28	28.07	21.12	31.21
Number of seeds/pod	11.46	12.71	12.77	12.62	12.60
100 Seed Weight (g)	30.81	32.83	30.97	32.68	30.47
Seed yield/Plant (g)	100.98	134.83	87.63	73.96	93.74

This cluster also reflected lowest cluster mean value for plant height (4.60), 100 seed weight (30.47), pod yield per plant (123.06) and pod length (14.69), day to pod initiation (69.90) and days to maturity (147.38) in the genotype. Cluster IV accommodated single genotypes which exhibits highest mean for days to maturity (199.89), tuber width (4.15) and 100 seed weight (32.08) and showed lowest accommodation for seed yield per plant (73.96) and number of pods per plant (21.12).

4.7.5. Percent contribution (%) of each character towards genetic divergence

The contribution percentage of sixteen traits towards genetic divergence is presented in Table 4.12. The highest contribution in the manifestation of

genetic divergence was exhibited by tuber weight (37.05%), followed by tuber width (13.85%), Days to first flowering (11.03%), tuber length (13.72%), dry pod weight (5.26%), plant height (4.36%), pod yield per plant (4.23%), seed yield per plant (4.10%), days to maturity (2.31%), number of pod per plant (1.67%), pod length (0.51%), 100 Seed Weight (0.90%), days to 50% flowering (0.90%) and the least contribution was shown by the pod width (0.13%) The extent of diversity in the present materials is tuber weight, tuber diameter, days to first flowering, dry pod weight, tuber length and plant height. All these characters offer a good scope for improvement in the plant yield through rational selection of parental genotypes.

Table 4.12: Percentage contribution of characters towards genetic diversity

Source	Times ranked 1 st	Contribution %
Plant height(m)	34	4.36%
Days to first Flowering	86	11.03%
Days to 50% Flowering	7	0.90%
Days to Pod initiation	0	0.00%
Days to Maturity	18	2.31%
Pod Length (cm)	4	0.51%
Pod Width (cm)	1	0.13%
Dry pod weight (g)	41	5.26%
Tuber length (cm)	107	13.72%
Tuber weight (g)	289	37.05%
Tuber Width (cm)	108	13.85%
Pod Yield/plant	33	4.23%
Number of pods/plants	13	1.67%
Number of seeds/pod	0	0.00%
100 Seed Weight (g)	7	0.90%
Seed yield/Plant (g)	32	4.10%

Out of 780 combinations, Tuber weight ranked 1st maximum times (289 times) found in tuber weight followed by tuber width (108), tuber length (107), days to first flowering (86), plant height (34), seed yield per plant (32), dry pod weight (41), pod yield per plant (33), Days to maturity (18), number of pod per plant (13), 100 seed weight (7), Days to 50% flowering (7), Pod length (4) and least by pod width (1) (only one time).

4.8. To assess G x E interaction and stability for yield and yield attributing traits

4.8.1. Pooled Analysis of variance based on Eberhart and Russel model

The pooled analysis of variance for phenotypic stability as per Eberhart and Russel (1966) indicated that mean differences due to genotypes were statistically significant towards most of the traits *i.e.* days to 1st flowering, days to 50 % flowering, days to maturity, number of pods per plant, number of seed per pod, seed index/100 seed weight, seed yield per plant, pod yield per plant, tuber diameter, tuber weight, tuber length, pod width, pod length, dry pod weight, days to pod initiation and Plant height when tested against G x E interaction (Table 4.6). This observationsuggested that, there is substantial variability in the genotypes evaluated. The highly significant G x E interaction observed for the trait's days to 1st flowering, days to 50 % flowering, seed index/100 seed weight, seed yield per plant, tuber weight, tuber length, pod length and Plant height indicated that genotypes showed varied response to different environment. On the other hand, The pooled analysis of variance on phenotypic stability as per Eberhart and Russel (1966) indicated that mean differences due to genotypes were statistically significant for the traits Plant height, days to first flowering, days to 50% flowering, days to maturity, days to pod initiation, , number of seed per pod, number of pods per plant, pod yield per plant, pod width (cm) seed yield per plant (g), dry pod weight (g), tuber length (cm), tuber diameter (cm), and tuber weight (g) except 100 Seed Weight (g)and pod length(cm), when tested against G x E interaction (Table 4.13). This observation suggested that, there is substantial variability in the genotypes evaluated.

Table 4.13: Analysis of variance for stability as per Eberhart and Russell Model (1966) in Winged bean.

Source of variation	Rep (Env.)	Genotypes	Env. + (Gen. X Env.)	Environments	Gen. X Env.	Environments (Lin.)	Gen. X Env. (Lin.)	Pooled Deviation	Pooled Error
DF	12	39	200	39	195	1	39	160	468
PH	0.31	4.55 ***	0.34 ***	8.71 ***	0.12	43.54 ***	0.10	0.13 ***	0.02
DFP	1.28	1763.20 ***	36.57 ***	38.20 **	36.53 ***	190.99 ***	145.62 ***	9.03 ***	1.45
DFPF	8.89	1887.48 ***	47.39 ***	710.46 ***	30.39 ***	3552.28 ***	117.23 ***	8.46 ***	5.30
DPI	9.41	1798.46 ***	30.27 ***	38.16 ***	30.07 ***	190.81 ***	126.63 ***	5.78 ***	6.38
DM	4.29	2255.46 ***	57.06	84.92	56.35	424.62 **	33.24	60.57 ***	7.57
PL	0.18	29.37 ***	2.49 ***	2.30	2.50 ***	11.48 **	6.39 ***	1.49 ***	0.20
PW	0.01	0.22 ***	0.04 *	0.05	0.04 *	0.26 **	0.07 ***	0.03 ***	0.01
DPW	0.01	4.74 ***	0.16	0.59 ***	0.15	2.95 ***	0.21 *	0.13 ***	0.02
TL	0.63	270.40 ***	5.94 ***	23.99 ***	5.48 ***	119.96 ***	17.38 ***	2.44 ***	0.79
TWE	2.03	1969.19 ***	10.26 **	8.24	10.31 **	41.20 *	24.44	6.61 ***	1.50
TWI	0.01	2.34 ***	0.04 *	0.26 ***	0.03	1.28 ***	0.05 *	0.03 ***	0.01
PYPP	21.48	8548.83 ***	295.14 *	842.38 **	281.10	4211.91 ***	501.63 ***	220.32 ***	42.12
NPPP	1.49	218.11 ***	26.22 ***	658.05 ***	10.02	3290.24 ***	16.57 **	8.17 ***	1.49
NSPP	0.25	10.46 ***	2.53 ***	57.14 ***	1.13 *	285.70 ***	2.33 ***	0.81 ***	0.34
SI	0.22	60.01 ***	6.99 ***	24.31 ***	6.54 ***	121.55 ***	16.33 ***	3.99 ***	0.28
SYPP	4.79	2228.28 ***	215.37 ***	6948.92 ***	42.71 **	34744.61 ***	95.42 ***	28.80 **	20.05

Table 4.14: Mean performance of winged bean genotypes for Plant height (m) and Days to first Flowering

Genotypes	Plant height (m)							Days to first Flowering						
	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ
LOCAL WOKHA-2	5.93	6.77	6.30	6.56	6.78	6.17	6.42	98.00	100.87	96.30	95.00	99.67	100.00	98.31
LOCAL SUCHONOMA	5.77	6.73	5.87	6.37	6.70	6.60	6.34	107.00	106.21	106.11	91.00	95.33	99.00	100.78
NUWB-4	5.70	7.73	6.73	7.58	7.80	7.32	7.14	114.00	111.66	114.35	121.00	116.33	114.78	115.35
LOCAL PEREN	3.70	5.33	4.30	5.33	5.00	4.60	4.71	125.00	124.83	122.89	122.00	119.00	121.00	122.45
LOCAL MEZDIPHEMA	5.10	6.43	5.43	5.58	5.31	5.78	5.61	89.00	89.63	89.88	84.33	90.00	85.33	88.03
VRWB-17	6.07	7.53	6.70	7.90	8.20	7.22	7.27	49.00	48.13	50.22	67.00	65.33	67.67	57.89
VRWB-20	5.13	6.60	5.87	4.95	5.86	5.80	5.70	57.00	56.36	57.58	67.00	66.67	67.00	61.93
VRWB-23	5.40	6.73	5.77	5.90	6.50	6.10	6.07	83.00	82.78	84.92	69.33	74.00	71.67	77.62
VRWB-24	4.93	6.20	5.33	5.74	7.50	5.43	5.86	81.00	83.21	79.42	90.00	84.33	81.00	83.16
NUWB-3	5.47	7.07	6.03	6.92	6.79	6.29	6.43	105.00	108.85	103.33	92.33	93.00	98.33	100.14
VRWB-26	5.73	7.07	6.07	5.50	5.20	5.50	5.85	89.00	87.48	90.28	74.33	74.33	82.33	82.96
VRWB-27	6.47	8.10	6.33	8.10	7.76	7.70	7.41	53.00	51.49	54.23	69.67	73.67	69.00	61.84
VRWB-68/NUWB-1	6.27	7.37	6.43	7.27	7.10	6.90	6.89	114.00	118.17	112.67	102.67	104.33	110.00	110.31
VRWB-32	4.23	5.47	4.70	4.40	5.00	4.90	4.78	96.00	95.87	94.04	87.67	92.33	92.67	93.10
VRWB-35	5.47	6.57	6.00	6.82	6.32	6.52	6.28	89.00	85.24	91.00	94.67	86.67	89.33	89.32
VRWB-36	5.71	6.73	6.37	7.33	7.80	7.20	6.86	101.00	103.40	99.46	98.33	99.00	103.00	100.70
LOCAL PANGTI-1	4.87	6.53	5.73	5.43	5.85	5.63	5.67	104.00	103.69	104.29	121.67	116.33	113.67	110.61
LOCAL DIMAPUR-1	5.40	6.60	6.53	6.75	6.64	6.91	6.47	112.00	108.07	114.65	92.00	90.33	94.33	101.90
VRWB-45	5.10	6.57	5.83	5.80	5.23	5.43	5.66	105.00	106.90	102.41	87.67	90.00	88.33	96.72
LOCAL PANGIT-2	3.67	5.27	4.23	5.40	5.00	4.85	4.74	123.00	125.23	121.86	120.33	119.33	123.33	122.18
LOCAL DIMAPUR-2	5.03	6.73	5.60	5.98	5.27	5.81	5.74	80.00	79.92	81.57	89.00	84.67	80.33	82.58
LOCAL AKUK	6.13	7.55	6.43	6.98	5.99	6.63	6.62	81.00	79.19	81.53	96.00	91.00	86.67	85.90
VRWB-50	4.10	5.47	4.60	5.18	5.02	4.87	4.87	91.00	95.16	89.11	101.00	96.67	91.67	94.10
VRWB-54	3.93	5.47	4.40	5.07	4.63	4.71	4.70	88.00	88.47	89.67	89.33	89.33	82.67	87.91
LOCAL WOKHA-1	3.90	5.61	4.37	4.66	4.42	4.78	4.62	98.00	100.91	95.81	103.33	101.33	99.00	99.73
VRWB-59	3.67	5.15	4.05	4.51	4.76	4.35	4.42	110.00	114.18	108.51	114.67	114.67	110.00	112.00
LOCAL DIMAPUR-3	6.67	7.20	7.20	7.60	8.01	7.38	7.34	123.00	119.57	124.89	125.00	131.00	124.67	124.69
VRWB-75	4.10	5.61	4.67	5.01	4.84	4.90	4.85	109.00	106.06	110.40	86.33	88.33	90.67	98.47
VRWB-77	6.32	6.90	6.93	7.09	6.67	7.22	6.86	87.00	84.76	88.06	92.00	84.33	86.44	87.10
VRWB-85	5.87	6.73	6.43	6.65	6.47	6.54	6.45	92.00	91.75	92.65	86.33	89.00	91.74	90.58
VRWB-88	4.53	5.33	4.97	5.60	6.01	5.26	5.28	105.00	105.44	105.75	86.00	78.00	89.00	94.87
LOCAL BAGHTY	5.23	6.07	5.87	5.41	5.85	5.74	5.69	96.00	97.78	94.84	83.00	85.67	90.33	91.27
VRWB-93	4.53	5.57	4.97	5.46	6.33	5.64	5.42	67.00	67.73	67.43	76.33	70.00	70.67	69.86
VRWB-100	4.30	6.07	4.83	4.49	4.92	4.93	4.92	75.00	74.55	73.60	76.00	78.33	79.67	76.19

VRWB-104	4.53	5.83	5.43	5.56	6.01	5.45	5.47	112.00	116.50	109.23	95.67	94.33	100.00	104.62
LOCAL MONSENTI	3.78	5.43	4.18	4.79	5.29	4.47	4.66	114.00	114.39	111.91	95.00	101.00	90.33	104.44
VRWB-112	4.50	6.07	5.10	5.85	5.55	5.49	5.43	76.00	75.13	75.51	75.67	78.67	77.67	76.44
VRWB-115	3.39	6.12	4.16	4.55	4.64	4.48	4.56	87.00	86.54	87.66	88.67	90.67	93.00	88.92
VRWB-116	5.38	7.13	5.92	5.96	6.59	6.29	6.21	124.00	125.74	121.04	126.67	131.67	128.67	126.30
NUWB-2	5.40	6.47	5.83	6.27	6.38	6.64	6.17	115.00	117.27	112.15	124.00	125.00	119.33	118.79
Mean	5.04	6.40	5.56	5.96	6.05	5.86		95.60	95.98	95.28	93.95	93.84	93.86	
C. V.	4.03	4.08	6.69	4.05	2.28	2.12		2.35	2.05	2.17	2.28	2.14	2.23	
SE	0.17	0.21	0.30	0.20	0.11	0.10		1.83	1.61	1.69	1.75	1.64	1.71	
CD 95%	0.33	0.43	0.61	0.39	0.22	0.20		3.65	3.20	3.36	3.48	3.26	3.41	

Table 4.15: Mean performance of winged bean genotypes for Days to 50% Flowering and Days to Pod initiation

Genotypes	Days to 50% Flowering							Days to Pod initiation						
	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.μ	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.μ
LOCAL WOKHA-2	129.99	134.13	132.00	122.00	126.00	127.51	128.60	106.00	106.00	107.65	89.00	103.00	97.33	101.50
LOCAL SUCHONOMA	145.76	144.56	146.00	133.00	132.00	128.48	138.30	113.00	113.00	115.29	97.33	106.17	103.67	108.08
NUWB-4	150.96	154.88	154.00	142.00	136.00	133.07	145.15	122.00	118.41	123.89	125.33	117.97	119.67	121.21
LOCAL PEREN	162.92	157.18	161.00	144.00	146.00	146.67	152.96	126.00	128.02	127.27	126.00	125.43	125.22	126.32
LOCAL MEZDIPHEMA	125.71	123.35	124.00	117.00	116.00	121.33	121.23	94.00	94.00	94.17	89.33	96.66	90.89	93.18
VRWB-17	80.73	76.50	79.00	86.00	84.00	87.00	82.20	54.00	54.00	54.92	71.67	54.36	72.67	60.27
VRWB-20	93.00	94.18	93.00	91.00	86.00	95.32	92.08	62.00	62.00	62.95	72.00	61.24	71.33	65.25
VRWB-23	125.90	131.84	128.00	102.00	106.00	112.00	117.62	87.00	87.00	87.20	74.33	89.41	76.67	83.60
VRWB-24	112.75	110.56	111.00	104.00	110.00	103.81	108.69	85.00	85.00	85.59	94.00	87.15	85.89	87.10
NUWB-3	149.29	156.25	153.00	128.00	127.00	125.23	139.79	114.00	114.00	113.98	97.67	110.69	105.67	109.34
VRWB-26	139.81	145.62	141.00	124.00	128.00	126.00	134.07	96.00	95.77	93.78	80.67	97.74	89.00	92.16
VRWB-27	89.52	87.81	89.00	90.00	93.00	86.48	89.30	63.00	63.00	62.06	74.33	62.85	74.33	66.60
VRWB-68/NUWB-1	160.95	153.59	159.00	137.00	137.00	134.99	147.09	117.00	117.00	118.06	106.33	111.94	113.33	113.94
VRWB-32	139.17	134.70	136.00	127.00	127.00	124.00	131.31	103.00	103.00	103.19	92.00	103.42	97.00	100.27
VRWB-35	125.04	130.75	127.00	133.00	126.00	129.81	128.60	91.00	91.00	89.30	98.33	91.36	94.00	92.50
VRWB-36	142.24	140.06	140.00	130.00	134.00	140.00	137.72	103.00	103.00	104.05	102.33	102.44	106.22	103.51
LOCAL PANGTI-1	151.00	149.85	152.00	136.00	142.00	149.00	146.64	111.00	111.00	112.98	128.33	108.38	123.67	115.89
LOCAL DIMAPUR-1	147.28	149.90	147.00	124.00	121.00	128.20	136.23	115.00	113.60	114.04	96.33	113.08	98.33	108.40
VRWB-45	138.68	138.48	139.00	108.00	121.00	118.00	127.19	113.00	113.00	114.90	91.67	113.31	99.00	107.48
LOCAL PANGIT-2	153.01	155.08	154.00	135.00	134.00	145.00	146.02	125.00	125.00	126.07	124.33	122.04	127.33	124.96
LOCAL DIMAPUR-2	108.28	107.29	109.00	101.00	102.00	107.22	105.80	83.00	83.00	83.72	92.33	82.32	84.56	84.82
LOCAL AKUK	115.02	113.39	115.00	119.00	109.00	117.10	114.75	88.00	88.00	86.06	99.00	89.57	91.67	90.38
VRWB-50	125.18	123.19	123.00	126.00	126.00	120.00	123.90	97.00	98.74	97.16	103.67	98.76	98.67	99.00
VRWB-54	114.27	112.57	114.00	116.00	115.00	112.81	114.11	90.00	91.25	90.57	93.67	91.48	87.11	90.68
LOCAL WOKHA-1	130.35	128.81	131.00	129.00	133.00	129.61	130.29	103.00	103.00	103.85	107.67	101.13	103.00	103.61
VRWB-59	136.04	139.45	138.00	136.00	136.00	132.00	136.25	113.00	113.00	112.49	119.67	114.89	114.33	114.56
LOCAL DIMAPUR-3	154.96	151.99	154.00	142.00	151.00	148.00	150.33	129.00	125.89	131.45	130.33	124.02	129.33	128.34
VRWB-75	136.01	143.72	139.00	124.00	120.00	120.00	130.46	110.00	113.35	108.99	91.00	113.79	92.33	104.91
VRWB-77	114.56	113.42	115.00	120.00	107.00	112.67	113.77	92.00	92.00	91.43	95.33	89.33	91.44	91.92
VRWB-85	119.12	117.67	118.00	118.00	120.00	118.00	118.46	97.00	97.00	97.20	90.33	97.86	95.98	95.90
VRWB-88	130.99	133.13	133.00	120.00	119.00	120.00	126.02	109.00	111.66	108.17	90.00	114.91	92.33	104.35
LOCAL BAGHTY	121.86	123.09	121.00	119.00	117.00	116.00	119.66	99.00	99.00	97.75	87.00	100.71	94.67	96.35
VRWB-93	94.91	98.13	96.00	96.00	98.00	94.00	96.17	69.00	69.00	70.33	80.33	67.75	74.67	71.85
VRWB-100	103.32	105.79	104.00	103.00	102.00	103.00	103.52	81.00	81.00	79.87	78.33	82.77	81.67	80.77

VRWB-104	143.00	140.28	143.00	120.00	122.00	127.87	132.69	113.00	112.65	112.86	98.00	111.40	103.00	108.49
LOCAL MONSENTI	133.94	136.12	136.00	124.00	131.00	124.00	130.84	113.00	119.08	111.28	99.00	115.43	94.33	108.69
VRWB-112	109.08	108.71	108.00	111.00	114.00	108.00	109.80	78.00	78.00	76.23	81.00	81.28	81.67	79.36
VRWB-115	117.37	110.66	115.00	112.00	115.00	120.41	115.07	88.00	88.00	87.62	93.00	85.60	93.67	89.31
VRWB-116	150.31	155.01	151.00	149.00	151.00	147.00	150.55	125.00	125.00	127.57	130.67	123.93	132.00	127.36
NUWB-2	140.70	144.49	144.00	152.00	140.00	140.00	143.53	120.00	120.00	122.48	128.33	122.63	123.67	122.85
Mean	129.07	129.40	129.30	121.25	121.50	121.99		99.93	100.14	100.21	98.00	99.71	98.28	
C. V.	2.33	2.33	1.99	1.98	2.05	6.28		2.08	6.80	2.14	2.20	6.89	2.83	
SE	2.46	2.47	2.10	1.96	2.03	6.25		1.69	5.56	1.75	1.76	5.61	2.27	
CD 95%	4.90	4.91	4.17	3.90	4.04	12.45		3.37	11.07	3.48	3.51	11.17	4.52	

Table 4.16: Mean performance of winged bean genotypes for Days to Maturity and Pod Length (cm)

Genotypes	Days to Maturity							Pod Length (cm)						
	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ
LOCAL WOKHA-2	197.00	195.00	194.22	207.33	206.33	191.00	198.48	17.93	18.26	19.04	16.20	16.75	16.93	17.52
LOCAL SUCHONOMA	199.00	197.00	194.56	206.33	204.67	194.00	199.26	23.34	24.04	24.41	17.87	18.89	19.75	21.38
NUWB-4	214.00	212.00	210.78	210.00	196.00	209.00	208.63	15.90	15.96	16.24	17.57	16.52	16.62	16.47
LOCAL PEREN	225.00	223.00	221.67	195.67	206.67	193.00	210.83	18.68	19.18	19.32	15.53	16.12	15.53	17.39
LOCAL MEZDIPHEMA	209.00	207.00	206.00	204.33	213.33	206.00	207.61	22.78	23.74	23.75	14.91	16.05	17.17	19.73
VRWB-17	141.00	140.00	137.33	149.33	147.33	169.00	147.33	14.89	15.18	15.22	17.37	16.35	15.64	15.77
VRWB-20	142.00	138.00	138.44	153.67	155.00	146.00	145.52	19.22	20.08	20.22	17.04	18.71	19.26	19.09
VRWB-23	183.00	182.00	180.89	160.67	165.67	173.00	174.20	14.68	15.40	14.91	13.91	15.14	16.07	15.02
VRWB-24	153.00	150.00	149.00	157.00	156.33	160.00	154.22	14.25	13.90	14.37	14.68	14.86	14.52	14.43
NUWB-3	225.00	224.00	221.22	204.33	201.00	210.00	214.26	14.42	13.91	14.18	14.52	14.79	15.32	14.52
VRWB-26	188.00	186.00	184.11	200.33	196.00	200.00	192.41	16.44	15.97	16.31	15.62	15.89	16.52	16.12
VRWB-27	137.00	135.00	134.22	147.33	156.67	140.00	141.70	13.66	13.84	13.83	14.57	14.49	13.46	13.98
VRWB-68/NUWB-1	213.00	212.00	209.00	183.00	183.00	182.00	197.00	17.19	17.04	16.29	16.03	16.47	16.40	16.57
VRWB-32	199.00	198.00	195.00	167.67	167.33	169.00	182.67	16.35	16.08	15.90	15.68	15.64	16.36	16.00
VRWB-35	181.00	179.00	177.89	208.33	188.33	185.00	186.59	15.32	14.77	14.76	13.93	14.05	14.29	14.52
VRWB-36	193.00	192.00	189.78	179.67	184.33	190.00	188.13	14.79	15.19	15.33	14.46	15.18	15.41	15.06
LOCAL PANGTI-1	204.00	202.00	200.00	209.67	214.67	208.00	206.39	16.73	17.21	16.93	15.86	16.37	16.99	16.68
LOCAL DIMAPUR-1	200.00	197.00	195.78	196.00	196.67	194.00	196.57	19.67	20.07	20.26	18.22	18.93	19.57	19.45
VRWB-45	190.00	189.00	187.11	201.00	195.00	192.00	192.35	15.34	15.13	15.03	15.08	14.94	15.38	15.15
LOCAL PANGIT-2	209.00	208.00	204.67	190.00	188.67	199.00	199.89	20.77	19.98	20.09	17.54	18.76	19.19	19.39
LOCAL DIMAPUR-2	165.00	164.00	161.33	178.33	173.33	171.00	168.83	20.35	20.09	20.20	17.66	18.64	18.95	19.32
LOCAL AKUK	174.00	172.00	170.44	174.33	183.00	178.00	175.30	10.29	9.96	9.84	16.93	17.82	18.48	13.89
VRWB-50	182.00	180.00	178.33	193.00	194.67	181.00	184.83	12.00	11.45	11.29	17.21	17.12	17.45	14.42
VRWB-54	160.00	159.00	157.22	164.67	171.67	164.00	162.76	14.42	13.88	14.15	15.20	15.41	16.15	14.87
LOCAL WOKHA-1	188.00	187.00	184.56	177.00	185.00	185.00	184.43	17.45	17.38	17.35	17.41	17.23	17.50	17.39
VRWB-59	194.00	193.00	192.11	175.67	178.33	186.00	186.52	12.45	12.06	12.98	15.02	14.39	13.40	13.38
LOCAL DIMAPUR-3	195.00	194.00	192.00	190.33	200.33	197.00	194.78	24.65	24.32	24.39	18.78	19.69	20.90	22.12
VRWB-75	189.00	187.00	185.78	193.67	191.33	187.00	188.96	13.78	13.78	13.93	18.04	18.73	19.08	16.22
VRWB-77	173.00	172.00	167.78	164.33	174.00	169.00	170.02	11.89	11.90	12.07	15.64	14.65	14.36	13.42
VRBW-85	175.00	173.00	172.11	176.00	167.67	180.00	173.96	13.67	12.91	13.32	15.47	14.42	13.71	13.92
VRWB-88	181.00	180.00	177.78	182.00	183.67	177.00	180.24	13.98	14.28	14.08	14.84	14.58	14.45	14.37
LOCAL BAGHTY	173.00	172.00	167.78	162.33	158.33	163.00	166.07	16.24	16.21	16.11	16.35	16.37	16.03	16.22
VRWB-93	149.00	145.00	144.67	154.67	153.33	147.00	148.94	15.36	15.84	16.15	15.35	15.76	16.31	15.80
VRWB-100	156.00	154.00	154.89	150.00	155.00	160.00	154.98	20.67	20.90	20.52	14.98	15.62	16.44	18.19

VRWB-104	195.00	194.00	158.11	182.67	189.00	189.00	184.63	19.88	19.95	19.67	17.46	17.22	17.66	18.64
LOCAL MONSENTI	188.00	187.00	185.78	176.00	167.67	178.00	180.41	16.46	16.65	16.26	14.68	15.32	16.44	15.97
VRWB-112	158.00	155.00	155.67	153.33	162.00	155.00	156.50	15.64	16.03	16.04	15.43	15.54	15.63	15.72
VRWB-115	167.00	164.00	165.44	165.67	160.67	164.00	164.46	15.52	15.15	14.89	15.62	15.29	14.65	15.19
VRWB-116	197.00	194.00	193.11	192.67	200.33	192.00	194.85	15.24	14.60	14.75	15.67	15.19	14.46	14.99
NUWB-2	186.00	185.00	183.22	185.00	184.67	183.00	184.48	20.47	20.21	20.07	16.57	17.22	21.45	19.33
Mean	183.68	181.93	179.49	180.58	181.43	180.40		16.57	16.56	16.61	16.02	16.28	16.60	
C. V.	1.98	1.84	5.08	1.45	1.44	2.15		7.54	2.18	2.53	2.98	4.93	5.72	
SE	2.97	2.73	7.44	2.14	2.13	3.17		1.02	0.30	0.34	0.39	0.66	0.78	
CD 95%	5.92	5.44	14.81	4.27	4.24	6.32		2.03	0.59	0.68	0.78	1.30	1.54	

Table 4.17: Mean performance of winged bean genotypes for Pod Width (cm) and Dry pod weight (g)

Genotypes	Pod Width (cm)							Dry pod weight (g)						
	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ
LOCAL WOKHA-2	2.47	2.40	2.60	2.43	2.47	2.57	2.49	5.45	5.98	5.45	5.11	4.92	5.16	5.35
LOCAL SUCHONOMA	2.57	2.30	2.40	2.37	2.40	2.30	2.39	5.13	5.39	5.92	5.48	5.21	5.91	5.51
NUWB-4	2.53	2.50	2.50	2.60	2.50	2.57	2.53	5.07	4.39	4.62	5.64	4.95	5.53	5.03
LOCAL PEREN	2.73	2.30	2.60	2.43	2.30	2.70	2.51	4.66	4.81	4.39	4.71	4.27	4.41	4.54
LOCAL MEZDIPHEMA	2.43	2.60	2.60	2.33	2.53	2.53	2.51	6.18	6.50	7.14	6.20	6.21	6.84	6.51
VRWB-17	2.70	2.40	2.70	2.47	2.40	2.70	2.56	6.87	5.95	6.26	6.76	6.43	6.39	6.44
VRWB-20	2.73	2.50	3.10	3.10	2.60	3.13	2.86	5.56	5.99	5.20	6.44	6.68	6.57	6.07
VRWB-23	2.40	2.80	2.30	2.47	2.47	2.40	2.47	4.72	4.96	5.44	4.15	4.25	5.07	4.76
VRWB-24	2.80	2.50	2.70	3.17	3.03	2.73	2.82	6.33	5.49	5.77	5.45	5.66	6.26	5.83
NUWB-3	2.43	2.60	2.40	2.27	2.57	2.37	2.44	3.83	4.15	3.60	3.50	4.34	4.41	3.97
VRWB-26	2.67	2.50	2.70	2.47	2.40	2.60	2.56	4.78	5.03	5.51	4.63	4.41	5.28	4.94
VRWB-27	2.57	2.50	2.40	2.57	2.53	2.40	2.49	5.96	5.17	5.43	5.77	5.53	5.09	5.49
VRWB-68/NUWB-1	2.57	2.90	2.80	2.23	2.93	2.77	2.70	4.06	4.46	3.87	4.56	4.77	4.23	4.33
VRWB-32	2.67	3.50	3.52	2.83	3.40	3.24	3.19	5.79	6.09	6.68	5.26	6.18	5.74	5.96
VRWB-35	2.50	2.70	2.60	2.56	2.60	2.61	2.60	4.23	3.88	3.86	3.45	3.96	4.54	3.99
VRWB-36	2.53	2.60	2.40	2.67	2.73	2.40	2.56	3.90	4.28	3.71	4.66	5.05	4.74	4.39
LOCAL PANGTI-1	2.43	2.60	2.50	2.60	2.50	2.60	2.54	5.10	5.36	5.89	5.42	4.78	5.36	5.32
LOCAL DIMAPUR-1	2.73	2.90	3.10	2.70	2.80	2.93	2.86	4.62	4.00	4.21	4.54	4.41	4.48	4.38
VRWB-45	2.47	2.60	2.90	2.47	2.60	2.90	2.66	5.25	5.77	5.00	5.31	5.73	5.75	5.47
LOCAL PANGIT-2	2.50	2.20	3.10	2.67	2.33	2.97	2.63	5.24	5.50	6.04	4.76	5.16	5.37	5.35
LOCAL DIMAPUR-2	2.87	2.50	3.00	3.07	2.60	3.07	2.85	6.23	5.40	5.68	5.87	5.53	5.62	5.72
LOCAL AKUK	2.43	2.80	2.60	2.63	2.60	2.50	2.59	6.46	7.09	6.14	7.23	6.88	7.27	6.85
VRWB-50	2.73	2.50	3.10	2.63	2.47	3.13	2.76	4.23	4.45	4.88	4.51	4.40	3.61	4.35
VRWB-54	2.70	2.40	3.30	2.73	2.47	3.27	2.81	4.00	4.62	4.21	4.62	4.19	5.38	4.50
LOCAL WOKHA-1	2.83	2.80	3.10	3.13	2.83	3.20	2.98	3.11	3.41	2.96	4.52	3.22	3.63	3.47
VRWB-59	2.53	2.50	2.50	2.90	2.63	2.50	2.59	4.26	4.48	4.91	4.72	4.23	4.70	4.55
LOCAL DIMAPUR-3	2.53	2.70	2.70	2.73	2.77	2.77	2.70	7.15	7.99	7.51	7.46	7.64	7.68	7.57
VRWB-75	2.47	2.60	3.10	2.77	2.53	3.03	2.75	4.18	3.62	3.81	4.05	3.63	4.22	3.92
VRWB-77	2.93	2.50	2.60	3.03	2.57	2.53	2.69	3.82	4.20	3.64	4.38	4.09	4.35	4.08
VRWB-85	2.67	2.40	2.40	2.47	2.47	2.30	2.45	4.50	4.73	5.19	4.55	4.67	4.49	4.69
VRWB-88	2.57	2.30	2.30	2.43	2.33	2.30	2.37	5.34	5.87	5.08	5.12	5.59	5.25	5.37
LOCAL BAGHTY	2.60	2.60	2.50	2.50	2.57	2.53	2.55	3.34	3.51	3.85	3.76	3.51	4.14	3.68
VRWB-93	2.57	2.40	2.50	2.47	2.50	2.67	2.52	4.72	4.09	4.30	5.14	5.29	5.28	4.80
VRWB-100	2.80	3.20	2.70	3.00	3.17	2.70	2.93	4.29	4.71	4.08	5.73	5.57	5.21	4.93

VRWB-104	2.63	3.10	2.50	2.27	2.97	2.53	2.67	4.79	5.04	5.53	6.12	5.49	6.32	5.55
LOCAL MONSENTI	2.57	2.60	2.45	2.20	2.47	2.40	2.45	5.17	4.48	4.71	4.87	4.74	4.68	4.78
VRWB-112	2.33	3.00	2.45	2.77	3.00	2.37	2.65	4.31	4.73	4.10	5.05	4.75	5.18	4.69
VRWB-115	2.47	2.80	2.20	2.50	2.70	2.60	2.55	3.72	3.91	4.29	4.17	4.33	5.19	4.27
VRWB-116	3.07	3.00	3.27	3.07	3.10	3.03	3.09	4.77	4.13	4.34	4.74	4.92	4.97	4.65
NUWB-2	2.40	2.40	2.29	2.30	2.43	2.70	2.42	4.49	4.93	4.27	4.38	4.64	4.93	4.61
Mean	2.60	2.63	2.69	2.63	2.63	2.69		4.89	4.96	4.94	5.07	5.01	5.23	
C. V.	7.94	7.45	3.22	5.67	4.61	4.67		4.68	4.66	4.62	3.72	4.85	4.36	
SE	0.17	0.16	0.07	0.12	0.10	0.10		0.19	0.19	0.19	0.15	0.20	0.19	
CD 95%	0.34	0.32	0.14	0.24	0.20	0.20		0.37	0.38	0.37	0.31	0.40	0.37	

Table 4.18: Mean performance of winged bean genotypes for Tuber length (cm)and Tuber weight (g)

Genotypes	Tuber length (cm)							Tuber weight (g)						
	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ
LOCAL WOKHA-2	31.00	31.90	29.05	32.64	25.49	30.29	30.06	31.51	34.59	29.98	31.00	31.70	32.90	31.95
LOCAL SUCHONOMA	22.33	22.45	24.64	22.69	22.34	22.93	22.90	45.28	47.60	52.24	48.00	48.39	48.12	48.27
NUWB-4	28.55	29.16	30.65	30.50	27.67	31.00	29.59	48.51	42.04	44.19	45.00	45.71	43.98	44.91
LOCAL PEREN	28.36	27.61	23.93	26.26	24.64	22.33	25.52	47.72	52.37	45.39	50.00	49.28	49.82	49.10
LOCAL MEZDIPHEMA	31.80	31.97	35.09	32.32	30.82	29.44	31.90	28.72	30.19	33.14	30.00	30.46	30.52	30.51
VRWB-17	19.66	20.08	21.10	21.00	21.22	21.69	20.79	38.39	33.27	34.98	36.00	35.53	34.81	35.50
VRWB-20	21.60	21.02	18.22	20.00	20.05	20.50	20.23	33.74	37.03	32.09	35.00	35.50	35.22	34.76
VRWB-23	29.13	29.19	29.56	40.00	40.15	40.41	34.74	45.65	47.99	52.67	49.00	48.22	48.51	48.67
VRWB-24	16.85	17.21	18.09	18.00	18.21	18.09	17.74	28.05	24.31	25.55	26.00	25.82	25.43	25.86
NUWB-3	41.04	39.94	34.62	38.00	38.65	38.28	38.42	32.96	36.18	31.35	33.50	33.45	34.41	33.64
VRWB-26	20.28	20.39	22.38	20.48	22.20	22.30	21.34	38.05	40.00	43.90	40.00	39.69	40.43	40.34
VRWB-27	9.80	10.00	10.52	10.47	10.29	12.83	10.65	33.36	28.91	30.39	30.00	30.06	30.24	30.49
VRWB-68/NUWB-1	19.44	18.92	16.40	18.00	17.83	18.25	18.14	56.32	61.81	53.57	60.00	59.66	58.80	58.36
VRWB-32	24.35	24.48	26.87	18.66	19.96	18.40	22.12	98.45	103.50	113.60	100.00	102.06	104.63	103.71
VRWB-35	19.67	20.09	21.12	24.75	23.37	24.79	22.30	41.17	35.68	37.51	37.00	36.95	37.33	37.61
VRWB-36	24.56	23.79	19.03	21.01	23.14	24.07	22.60	27.17	29.81	25.84	28.00	27.97	28.36	27.86
LOCAL PANGTI-1	32.21	29.63	33.70	32.00	29.41	31.22	31.36	59.54	62.59	68.70	62.00	61.27	63.27	62.89
LOCAL DIMAPUR-1	17.89	15.05	16.47	18.18	18.95	18.97	17.59	52.67	45.65	47.98	47.00	48.56	47.38	48.21
VRWB-45	12.90	13.81	11.41	14.00	13.30	13.42	13.14	19.40	21.29	18.45	20.00	19.81	20.25	19.87
LOCAL PANGIT-2	23.30	22.68	19.65	21.57	23.66	24.00	22.48	47.08	49.49	54.32	50.00	49.77	50.03	50.11
LOCAL DIMAPUR-2	22.63	22.75	24.97	23.00	22.52	21.68	22.93	25.14	21.79	22.90	23.00	22.54	22.79	23.03
LOCAL AKUK	24.34	24.86	26.13	26.00	25.35	26.52	25.53	37.60	41.27	35.76	40.00	39.08	39.26	38.83
VRWB-50	34.13	33.22	28.79	31.60	32.80	30.81	31.89	39.42	41.44	45.49	42.00	41.86	41.90	42.02
VRWB-54	32.66	32.84	36.04	33.19	31.50	32.46	33.12	56.96	49.36	51.89	50.00	50.82	51.63	51.78
LOCAL WOKHA-1	30.15	30.79	32.37	32.21	32.61	33.73	31.98	42.16	46.27	40.11	46.00	44.73	44.02	43.88
VRWB-59	34.56	33.64	29.16	32.01	29.88	29.90	31.52	102.63	107.89	118.41	89.00	109.48	86.67	102.35
LOCAL DIMAPUR-3	23.82	23.95	26.29	24.21	25.46	25.82	24.92	18.98	19.95	21.89	32.00	31.12	31.11	25.84
VRWB-75	21.75	20.03	24.00	22.10	22.83	21.32	22.00	34.31	29.74	31.26	20.00	19.48	20.16	25.83
VRWB-77	16.59	16.95	17.81	17.73	18.26	17.94	17.55	27.47	30.15	26.12	29.00	28.86	28.67	28.38
VRWB-85	22.00	21.00	22.78	25.00	23.91	24.29	23.16	46.08	48.45	53.17	50.00	49.48	48.97	49.36
VRWB-88	28.00	28.00	31.67	35.18	34.33	34.67	31.97	38.55	42.31	36.67	40.00	40.26	40.25	39.68
LOCAL BAGHTY	24.00	24.33	27.33	35.00	33.30	35.54	29.92	55.55	58.40	64.09	60.00	59.27	59.03	59.39
VRWB-93	19.00	24.12	23.33	29.51	31.74	31.72	26.57	20.35	17.64	18.55	18.00	18.19	18.45	18.53
VRWB-100	33.60	32.18	27.10	35.19	33.33	32.33	32.29	27.25	29.91	25.92	27.00	27.85	28.31	27.71

VRWB-104	12.30	12.36	13.57	12.50	13.14	12.96	12.80	28.31	29.76	32.66	30.00	29.78	30.08	30.10
LOCAL MONSENTI	27.00	27.56	24.17	34.00	33.76	34.12	30.10	34.57	29.96	31.49	31.00	31.51	31.34	31.65
VRWB-112	27.00	26.33	21.33	35.00	32.79	30.67	28.85	48.13	52.82	45.78	48.00	49.00	50.25	49.00
VRWB-115	15.57	15.65	17.17	15.82	17.23	15.73	16.20	42.34	44.51	48.85	45.00	44.68	44.99	45.06
VRWB-116	14.66	14.97	15.74	15.66	15.76	16.36	15.52	58.67	50.85	53.46	50.00	51.56	53.19	52.96
NUWB-2	24.09	23.45	20.33	22.31	24.48	25.00	23.28	27.64	30.34	26.29	30.00	29.43	28.86	28.76
Mean	24.06	23.96	23.82	25.44	25.16	25.42		41.65	42.18	42.67	41.44	41.97	41.61	
C. V.	7.68	8.09	7.08	5.79	4.22	3.69		6.49	6.53	6.87	2.62	2.03	3.06	
SE	1.51	1.58	1.38	1.20	0.87	0.77		2.21	2.25	2.39	0.89	0.70	1.04	
CD 95%	3.00	3.15	2.74	2.40	1.72	1.53		4.39	4.47	4.77	1.77	1.38	2.07	

Table 4.19: Mean performance of winged bean genotypes for Tuber diameter (cm) and Pod yield per plant

Genotypes	Tuber Diameter (cm)							Pod yield per plant						
	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ
LOCAL WOKHA-2	3.05	3.10	2.74	3.05	2.91	2.95	2.97	186.51	225.85	227.55	192.66	186.29	192.67	201.92
LOCAL SUCHONOMA	2.34	2.30	2.70	2.34	2.37	2.35	2.40	192.41	157.04	167.63	150.69	155.84	159.45	163.85
NUWB-4	1.58	1.53	1.50	1.58	1.45	1.46	1.52	166.12	196.13	168.79	179.78	158.31	151.13	170.05
LOCAL PEREN	2.06	2.00	2.40	2.06	2.07	2.06	2.11	216.06	247.48	222.67	179.20	162.76	174.35	200.42
LOCAL MEZDIPHEMA	2.16	2.10	2.40	2.16	2.33	2.28	2.24	195.87	234.90	219.75	224.42	224.38	223.03	220.39
VRWB-17	1.92	2.09	2.10	1.92	2.17	2.20	2.07	224.76	254.18	219.48	296.29	282.14	279.35	259.37
VRWB-20	2.02	2.17	2.10	2.02	2.34	2.32	2.16	231.30	259.88	231.82	255.98	270.57	280.22	254.96
VRWB-23	1.35	1.43	1.60	1.35	1.29	1.32	1.39	148.67	155.46	142.00	175.65	178.52	171.80	162.02
VRWB-24	3.53	3.42	3.80	3.53	3.29	3.30	3.48	192.34	178.99	188.60	221.52	235.66	231.99	208.18
NUWB-3	2.02	1.92	2.30	2.02	1.81	1.80	1.98	101.00	109.06	91.67	93.39	119.88	136.56	108.59
VRWB-26	2.53	2.50	2.40	2.53	2.58	2.53	2.51	202.87	206.67	198.56	180.70	184.82	172.08	190.95
VRWB-27	2.75	2.80	2.90	2.75	2.80	2.75	2.79	185.33	189.86	182.46	221.75	214.11	225.28	203.13
VRWB-68/NUWB-1	1.98	1.51	1.60	1.98	1.73	1.70	1.75	127.00	117.56	136.31	128.23	133.07	133.52	129.28
VRWB-32	1.22	1.20	1.20	1.22	1.23	1.22	1.21	160.67	180.74	139.71	148.33	187.36	187.97	167.46
VRWB-35	1.91	2.00	2.30	1.91	1.96	1.91	2.00	125.16	172.38	141.43	114.65	133.81	141.61	138.17
VRWB-36	2.38	2.30	2.30	2.38	2.42	2.38	2.36	176.44	172.67	172.00	174.91	186.98	206.87	181.64
LOCAL PANGTI-1	2.27	2.27	2.10	2.27	2.42	2.40	2.29	134.04	181.78	150.09	170.80	154.85	161.50	158.84
LOCAL DIMAPUR-1	2.91	3.00	3.20	2.91	2.96	2.91	2.98	133.81	156.33	161.86	137.59	137.44	138.83	144.31
VRWB-45	1.53	1.56	2.00	1.53	1.72	1.70	1.67	175.82	167.67	178.44	197.24	213.29	213.37	190.97
LOCAL PANGIT-2	3.96	4.27	4.50	3.96	4.12	4.10	4.15	126.33	139.33	124.41	111.59	119.40	117.32	123.06
LOCAL DIMAPUR-2	2.37	2.30	2.30	2.37	2.39	2.37	2.35	156.40	183.00	180.60	205.71	193.70	183.47	183.81
LOCAL AKUK	2.50	2.33	2.70	2.50	2.16	2.20	2.40	149.64	162.67	158.67	172.75	166.14	164.34	162.37
VRWB-50	3.00	3.16	3.20	3.00	2.99	3.00	3.06	126.67	130.22	125.29	148.65	144.43	151.41	137.78
VRWB-54	2.57	2.60	2.80	2.57	2.58	2.57	2.62	119.33	142.00	120.31	142.39	128.08	131.01	130.52
LOCAL WOKHA-1	2.55	3.10	3.30	2.55	3.05	3.11	2.94	125.27	136.00	134.23	164.85	115.35	110.83	131.09
VRWB-59	3.11	3.30	3.00	3.11	3.29	3.34	3.19	146.19	152.00	173.46	166.97	153.16	150.62	157.07
LOCAL DIMAPUR-3	1.98	1.80	2.50	1.98	1.77	1.73	1.96	206.00	196.00	201.92	233.94	237.11	240.04	219.17
VRWB-75	3.23	2.50	3.30	3.23	2.38	2.40	2.84	130.00	133.67	138.42	134.97	119.64	117.00	128.95
VRWB-77	3.13	3.20	3.70	3.13	3.15	3.13	3.24	111.31	121.45	123.73	134.47	127.15	132.37	125.08
VRBW-85	2.40	2.40	2.60	2.40	2.32	2.33	2.41	187.64	182.15	162.32	198.02	200.85	202.94	188.99
VRWB-88	1.98	2.23	2.20	1.98	1.93	1.98	2.05	184.72	194.88	163.11	208.13	212.48	217.90	196.87
LOCAL BAGHTY	3.23	3.20	3.60	3.23	3.24	3.24	3.29	103.29	114.95	113.47	111.08	101.36	100.29	107.41
VRWB-93	2.30	2.45	2.90	2.30	2.37	2.39	2.45	178.47	70.06	168.70	172.80	180.95	167.50	156.41
VRWB-100	1.77	2.89	2.30	1.86	3.05	3.02	2.48	228.89	213.56	231.93	219.79	218.02	228.11	223.38

VRWB-104	2.06	1.80	2.00	2.06	1.74	1.77	1.91	142.42	147.36	164.67	163.49	147.94	155.42	153.55
LOCAL MONSENTI	2.40	2.56	2.60	2.40	2.53	2.53	2.50	139.30	132.46	152.25	133.49	132.29	134.85	137.44
VRWB-112	3.13	3.11	3.40	3.13	3.27	3.30	3.22	149.09	164.47	167.13	170.64	165.71	174.15	165.20
VRWB-115	1.37	1.65	2.10	1.37	1.81	1.80	1.69	116.41	121.10	116.74	124.61	131.37	138.49	124.79
VRWB-116	2.06	2.04	2.50	2.06	2.20	2.20	2.18	181.61	169.86	180.35	187.25	182.21	169.92	178.53
NUWB-2	3.02	3.14	3.10	3.02	3.26	3.30	3.14	150.33	151.00	151.81	132.35	142.04	128.68	142.70
Mean	2.39	2.43	2.61	2.39	2.44	2.43		160.89	168.07	164.86	172.04	170.99	172.46	
C. V.	6.50	6.14	7.66	6.50	7.66	1.96		4.92	10.00	5.46	4.52	5.78	7.65	
SE	0.13	0.12	0.16	0.13	0.15	0.04		6.47	13.72	7.34	6.35	8.08	10.77	
CD 95%	0.25	0.24	0.32	0.25	0.30	0.08		12.87	27.31	14.62	12.64	16.08	21.44	

Table 4.20: Mean performance of winged bean genotypes for Number of pods per plant and Number of seeds per pod

Genotypes	Number of pods per plant							Number of seeds per pod						
	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ
LOCAL WOKHA-2	28.67	38.33	34.44	37.72	38.46	37.80	35.90	11.00	11.33	11.00	11.00	12.00	11.23	11.26
LOCAL SUCHONOMA	26.00	33.00	28.08	27.51	30.00	29.52	29.02	12.00	13.00	13.00	13.00	14.00	15.12	13.35
NUWB-4	29.00	34.67	33.05	31.85	31.94	28.64	31.52	8.67	10.67	9.00	10.00	12.00	11.81	10.36
LOCAL PEREN	33.00	38.00	33.59	38.02	37.18	36.86	36.11	12.67	10.67	10.00	14.00	12.00	11.23	11.76
LOCAL MEZDIPHEMA	28.00	34.00	31.82	36.16	35.89	33.45	33.22	13.60	12.55	11.23	12.87	13.87	14.98	13.18
VRWB-17	43.00	48.33	46.44	43.81	44.83	40.25	44.44	11.40	13.75	12.77	10.36	14.56	14.33	12.86
VRWB-20	41.00	46.00	39.95	39.74	40.89	43.85	41.90	11.47	13.92	13.76	13.00	15.00	14.04	13.53
VRWB-23	33.00	38.33	34.63	42.33	41.66	36.41	37.73	11.67	12.33	10.00	11.00	13.00	14.04	12.01
VRWB-24	43.00	47.33	45.79	40.69	41.50	39.69	43.00	10.00	11.67	12.00	9.00	11.00	10.82	10.75
NUWB-3	18.00	23.33	23.62	26.67	28.13	25.92	24.28	11.33	13.00	13.00	10.00	12.00	11.23	11.76
VRWB-26	32.67	36.67	37.44	39.04	40.63	39.36	37.64	11.67	13.33	13.00	12.00	15.00	16.20	13.53
VRWB-27	34.33	39.33	39.03	38.46	40.06	33.82	37.51	8.33	12.33	12.00	10.00	14.00	13.78	11.74
VRWB-68/NUWB-1	19.67	33.00	22.57	28.12	27.62	24.77	25.96	11.00	14.33	14.00	12.00	15.00	14.04	13.40
VRWB-32	23.00	38.00	23.15	31.28	30.69	24.34	28.41	11.00	14.00	14.00	11.00	15.00	16.20	13.53
VRWB-35	22.00	40.00	32.40	34.60	33.34	28.08	31.74	8.67	12.67	13.00	9.00	12.00	11.81	11.19
VRWB-36	34.00	52.67	44.41	37.52	37.34	48.74	42.45	11.00	12.33	12.00	10.00	13.00	12.17	11.75
LOCAL PANGTI-1	19.00	31.00	29.02	31.54	34.00	30.50	29.18	10.33	12.00	11.00	12.00	13.00	14.04	12.06
LOCAL DIMAPUR-1	20.67	33.67	23.04	30.34	31.94	19.97	26.60	11.67	13.67	15.00	13.00	14.00	13.78	13.52
VRWB-45	25.00	45.67	31.49	37.16	36.50	34.56	35.06	10.00	13.00	13.00	11.00	12.00	11.23	11.71
LOCAL PANGIT-2	17.33	26.33	18.10	23.43	22.50	19.03	21.12	11.00	13.67	14.00	10.00	13.00	14.04	12.62
LOCAL DIMAPUR-2	24.33	25.33	31.97	35.05	34.18	27.70	29.76	8.00	12.00	12.00	7.00	13.00	12.79	10.80
LOCAL AKUK	14.67	22.67	17.65	23.89	23.97	19.37	20.37	6.00	8.33	8.00	7.00	10.00	9.36	8.12
VRWB-50	25.33	42.33	30.07	32.96	33.11	31.61	32.57	7.00	9.67	9.00	8.00	11.00	11.88	9.42
VRWB-54	21.00	37.67	27.00	30.81	31.77	23.40	28.61	8.33	11.00	10.00	7.00	12.00	11.81	10.02
LOCAL WOKHA-1	24.33	46.00	26.90	36.50	35.48	29.52	33.12	8.00	11.33	11.00	9.00	12.00	11.23	10.43
VRWB-59	28.33	41.33	30.51	35.34	36.48	32.08	34.01	10.00	13.00	13.00	9.00	12.00	12.96	11.66
LOCAL DIMAPUR-3	23.00	36.00	22.78	31.36	31.32	23.94	28.07	12.00	13.67	15.00	11.00	12.00	12.96	12.77
VRWB-75	19.33	38.00	27.65	33.29	33.13	23.96	29.23	10.00	14.00	13.00	10.00	14.00	13.78	12.46
VRWB-77	20.33	31.33	21.65	30.68	31.56	23.76	26.55	10.00	13.00	13.00	11.00	12.00	11.23	11.71
VRBW-85	25.67	45.00	32.57	43.53	42.62	34.24	37.27	9.33	12.67	13.00	9.00	14.00	15.12	12.19
VRWB-88	32.67	49.00	39.36	40.67	38.00	43.20	40.48	8.33	9.33	8.00	8.00	11.00	10.30	9.16
LOCAL BAGHTY	17.33	26.00	20.09	29.55	29.01	21.12	23.85	8.67	12.00	12.00	7.00	11.00	11.88	10.42
VRWB-93	20.67	36.00	29.88	33.60	34.68	25.90	30.12	11.00	14.33	15.00	10.00	13.00	12.79	12.69
VRWB-100	30.00	46.33	35.88	38.36	39.69	39.38	38.28	10.67	13.00	14.00	11.00	12.00	11.23	11.98

VRWB-104	21.67	32.67	23.09	26.72	27.64	24.27	26.01	8.00	11.00	12.00	9.00	10.00	10.80	10.13
LOCAL MONSENTI	26.33	45.67	31.82	27.40	29.00	27.58	31.30	10.67	13.00	12.00	11.00	14.00	13.78	12.41
VRWB-112	28.33	43.33	37.36	33.81	35.76	41.00	36.60	9.00	11.33	11.00	11.00	13.00	12.17	11.25
VRWB-115	24.00	43.33	26.52	29.85	30.48	27.88	30.34	9.33	10.33	9.00	11.00	10.00	10.80	10.08
VRWB-116	30.33	45.67	41.04	39.51	36.00	35.57	38.02	9.67	12.00	13.00	8.67	11.00	10.82	10.86
NUWB-2	22.33	37.33	23.94	30.18	30.00	26.28	28.34	10.00	14.00	14.00	10.67	13.00	12.17	12.31
Mean	26.26	38.22	30.75	33.98	34.22	30.93		10.06	12.33	12.09	10.24	12.64	12.65	
C. V.	8.42	4.92	7.63	2.65	7.50	7.61		12.61	9.23	7.50	7.56	7.47	7.48	
SE	1.81	1.53	1.92	0.74	2.10	1.92		1.04	0.93	0.74	0.63	0.77	0.77	
CD 95%	3.59	3.05	3.81	1.47	4.17	3.82		2.06	1.85	1.47	1.26	1.53	1.54	

Table 4.21: Mean performance of winged bean genotypes for 100 Seed weight (g) and Seed yield per plant (g)

Genotypes	100 Seed weight (g)							Seed yield per plant (g)						
	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ	Env. 1	Env. 2	Env. 3	Env. 4	Env. 5	Env. 6	Gen.µ
LOCAL WOKHA-2	37.53	38.54	36.21	28.42	28.93	28.68	33.05	151.45	130.23	114.36	142.38	110.00	121.12	128.26
LOCAL SUCHONOMA	35.22	35.36	34.26	35.93	35.42	36.62	35.47	135.42	92.50	100.86	128.72	102.34	108.00	111.31
NUWB-4	38.20	40.33	37.47	35.12	34.87	35.54	36.92	121.46	104.94	81.93	124.76	104.25	98.00	105.89
LOCAL PEREN	29.26	30.92	32.74	23.28	24.32	23.44	27.33	104.60	76.70	93.63	105.21	81.94	88.00	91.68
LOCAL MEZDIPHEMA	30.99	32.30	32.63	32.95	33.31	32.93	32.52	130.13	105.42	89.24	133.42	107.21	92.00	109.57
VRWB-17	29.61	30.64	31.93	33.21	35.43	33.64	32.41	162.59	135.37	129.19	165.90	135.66	114.00	140.45
VRWB-20	30.41	32.19	32.65	39.99	40.54	40.10	35.98	175.30	145.32	123.20	176.31	163.28	131.00	152.40
VRWB-23	31.58	30.55	33.86	29.96	29.78	30.03	30.96	146.32	113.25	98.00	138.43	118.21	93.00	117.87
VRWB-24	31.37	31.88	32.95	23.68	24.34	24.13	28.06	107.71	90.77	94.32	111.68	85.42	102.00	98.65
NUWB-3	31.87	31.52	31.56	35.77	36.23	35.25	33.70	107.91	81.95	83.64	113.20	88.04	76.42	91.86
VRWB-26	32.81	34.60	35.55	34.94	35.11	35.47	34.75	144.97	133.28	112.00	159.69	141.06	104.00	132.50
VRWB-27	29.33	30.61	31.90	28.73	30.44	29.62	30.11	114.06	115.62	103.37	127.14	109.14	100.43	111.63
VRWB-68/NUWB-1	29.39	29.57	27.84	26.33	25.33	26.15	27.43	85.74	79.10	73.24	85.51	72.00	66.65	77.04
VRWB-32	29.67	32.33	33.86	22.37	21.57	21.88	26.95	79.54	71.08	62.10	79.06	68.00	59.20	69.83
VRWB-35	29.59	32.57	31.84	26.99	26.79	28.66	29.41	104.06	88.00	83.00	103.93	92.40	78.10	91.58
VRWB-36	30.63	32.24	31.98	26.76	26.43	26.82	29.14	143.33	120.13	107.38	138.44	127.38	109.00	124.28
LOCAL PANGTI-1	37.55	39.61	41.87	33.19	32.35	34.33	36.48	124.00	113.67	97.90	121.05	103.21	88.76	108.10
LOCAL DIMAPUR-1	39.92	42.12	41.58	36.25	36.13	36.67	38.78	119.24	107.74	93.32	126.18	104.03	99.85	108.39
VRWB-45	25.97	27.85	29.35	29.60	30.12	28.61	28.58	123.83	112.28	89.82	124.76	105.21	95.00	108.48
LOCAL PANGIT-2	31.63	31.82	35.28	31.52	33.23	32.59	32.68	87.15	69.00	61.33	88.98	73.55	63.78	73.96
LOCAL DIMAPUR-2	31.90	34.31	34.27	29.29	28.77	29.62	31.36	112.42	91.00	84.00	114.45	98.07	80.33	96.71
LOCAL AKUK	31.94	31.86	33.79	24.95	25.37	25.98	28.98	84.71	73.00	68.45	89.19	78.45	72.00	77.63
VRWB-50	23.52	24.47	25.47	25.88	25.35	25.83	25.09	95.41	78.09	67.59	97.49	73.32	61.09	78.83
VRWB-54	29.56	31.96	34.28	34.38	35.43	34.81	33.41	121.12	84.00	76.00	121.31	98.25	73.28	95.66
LOCAL WOKHA-1	23.66	25.18	25.86	24.80	26.46	24.09	25.01	107.68	88.00	69.60	106.00	96.65	71.00	89.82
VRWB-59	33.50	34.19	33.85	34.07	33.37	34.93	33.98	125.69	119.42	105.82	135.40	116.50	103.00	117.64
LOCAL DIMAPUR-3	31.71	32.78	30.63	30.61	29.79	30.28	30.97	105.89	81.60	72.93	106.60	80.78	78.00	87.63
VRWB-75	31.85	33.88	33.74	30.08	29.35	30.11	31.50	108.53	82.00	78.62	109.52	88.59	69.90	89.53
VRWB-77	29.60	32.66	30.73	25.43	24.25	25.04	27.95	85.71	73.00	62.71	89.77	78.19	67.00	76.06
VRBW-85	28.09	30.73	30.55	29.83	26.45	28.89	29.09	132.87	111.55	93.28	130.53	113.12	101.00	113.72
VRWB-88	24.67	24.34	27.44	35.67	34.53	35.10	30.29	154.81	125.83	108.00	143.88	132.56	110.00	129.18
LOCAL BAGHTY	29.05	29.64	28.34	26.51	27.34	27.04	27.99	88.84	80.00	66.91	90.20	84.70	73.00	80.61
VRWB-93	28.30	29.37	27.34	32.26	33.23	30.39	30.15	119.55	88.08	78.26	125.60	92.80	85.00	98.22
VRWB-100	29.34	28.34	26.34	30.54	30.45	30.23	29.21	121.39	115.27	104.55	129.02	111.98	110.00	115.37

VRWB-104	30.93	31.67	32.24	31.73	32.05	32.35	31.83	100.09	80.79	69.66	100.59	77.78	73.00	83.65
LOCAL MONSENTI	27.30	29.89	28.32	32.59	32.16	32.59	30.48	100.94	105.00	92.43	103.71	82.91	88.75	95.62
VRWB-112	28.64	29.90	29.24	31.72	32.64	32.24	30.73	118.40	112.18	93.87	125.71	107.00	99.72	109.48
VRWB-115	28.31	30.77	31.23	30.24	30.24	31.37	30.36	101.67	88.75	71.00	105.62	83.81	67.00	86.31
VRWB-116	28.34	29.42	30.34	28.18	28.46	28.96	28.95	125.41	114.36	104.53	121.06	110.00	98.25	112.27
NUWB-2	28.65	31.12	34.23	32.23	32.47	32.95	31.94	106.21	97.12	90.83	111.76	94.00	88.75	98.11
Mean	30.53	31.85	32.14	30.40	30.47	30.60		117.15	99.39	88.77	118.80	99.80	88.96	
C. V.	4.24	4.21	2.01	2.14	1.87	1.88		7.51	7.52	7.56	7.54	7.58	7.55	
SE	1.06	1.10	0.53	0.53	0.46	0.47		7.18	6.10	5.48	7.31	6.18	5.49	
CD 95%	2.10	2.18	1.05	1.06	0.92	0.94		14.30	12.15	10.91	14.56	12.30	10.92	

The significance of pooled deviation (non-linear) effects of the traits viz., days to 1st flowering, days to 50 % flowering, days to maturity, number of pods per plant, number of seed per pod, seed index/100 seed weight, seed yield per plant, pod yield per plant, tuber diameter, tuber weight, tuber length, pod width, pod length, dry pod weight, days to pod initiation and Plant height as depicted in Table 4.13.

4.8.2. Mean performance of Winged bean genotypes for sixteen traits over six environments.

4.8.2.1. Plant height:

Genotype tallest (in table 4.14) across the environment in E1, Local Dimapur-3 (6.67) followed by E2, VRRB-27 (8.10) and in E3, Local Dimapur-3 (7.6) in E4 VRWB-27 (8.10), in E5 local Medziphema (8.20) and in E6 VRWB-27 (7.70) (Table 4.7) on the other hand genotype shows minimum value across environment are, in E1 VRWB-115 (3.39), in E2 VRWB-59 (5.12), in E3 VRWB-59 (4.10), in E4 (4.49), in E5 Local Wokha-1(4.42) and in E6 (4.35) VRWB-59. The mean Germination percentage was maximum in E2 (6.40) followed by E5 (6.05), E4 (5.96), E6 (5.86), E3 (5.78) and E1(5.04).

4.8.2.2. Days to first flowering:

The earliest genotype for Days to first flowering (in table 4.14) across the four environment was VRWB-17 in all environment *i.e.* in E2 (48.13), in E1 (49.00 days), followed by E3 (50.22 days) in E5 (65.33 days), in E4 (67.00) and E6 (67.67 days) (Table 4.7) on the other hand genotype shows maximum days as a late value across environment are, in E5 VRWB-116 (131.67), in E6 VRWB-116 (128.67), in E4 VRWB-116 (126.67), in E2 (125.23) Local Pangti-2, in E1 Local Peren (125.00) and in E6 (124.89) Local dimpaur-3. The mean Days to first flowering was earliest in E5 (93.84 days) followed by E6 (93.86 days), E6 (93.86 days), E3 (93.95 days), E2 (95.28 days) and E1 (95.98 days) in all environments.

4.8.2.3. Days to 50% flowering:

The earliest genotype for days to 50 % flowering (in table 4.15) across the six environments was (76.50 days) in E2 followed by. VRWB (79.00 days) in E3, VRWB-17 (79.00 days) in E3 VRWB-17 (80.73 days) in E5 (84.00 Days), in E4 (86.00 days) VRWB-17 and VRWB_17 E6 (86.58 days) on the other hand the late observed genotypes are, E1 (162.92 days) Local peren followed by E3 (161.00) Local peren, in E2 (157.18 days), in E4 (152.00 days) NUWB-2, in E5 (151.00 days) VRWB-116 and E6 Local Pangti-1(149.00 days). The mean days to 50% flowering time was earliest in E4 environment i.e., (121.25 days) followed by E5 (121.50 days),) E6 (121.99 days), E1 (129.07 days), E2 (129.40 days) and E3 (129.30 days) in all 6 environments.

4.8.2.4. Days to pod initiation:

Among the genotype with early pod initiation (in table 4.15) isVRWB-17 for all conditions *i.e.* E1 (54.00 days), in E2 (54.00 days), E5 (54.23 days), followed by E4 (71.67 days) and E6(72.67 days) while the genotypes with late pod initiation are E3 (131.45 days), followed by (130.33 days) in E4, in E6 (129.33 days) local Dimapur-3 , E1and E2 (129.00 days) respectively and E5 with (125.77days).The mean for days to pod initiation was earliest in E3 environment i.e., (98.00 days) followed by E6 (98.28 days),) E5 (99.71 days), E1 (99.93 days), E2 (100.14 days) and E3 (100.23 days) in all 6 environments.

4.8.2.5. Days to maturity:

Among the genotypes the earliest maturity (in table 4.16) was observed in the following genotypes *i.e.* In E4 (134.00 days) VRWB-27 followed by E2 (135.00 days) VRWB-27, in E1 (137.00 days) VRWB-27, in E6 (140.00 days) VRWB-27, in E4 and E6 (147.33 days) VRWB-27 and VRWB-17 respectively .while all environment exhibits late maturity value in the NUWB-3 genotype in E1 (225.00 days),E2 (224.00 days), E3 (21.00 days) and E6 (210.00 days) also Local Pangti -1 (214.0 days)in E6 and NUWB-4 (210.00days) in E5. The mean for days to maturity was earliest in E3 environment i.e., (179.00 days) followed

by E5 (181.43 days), E6 (181.43 days), E2 (181.93 days), E1 (183.68 days) and E4 (180.58 days) in all 6 environments.

4.8.2.6. Pod length (cm):

The highest pod length (in table 4.16) among the genotypes is found to be in Local Suchonoma in E3 (24.41), E2(24.04), E5 (18.89), E1 (23.14) followed by NUWB-2 in E6 (21.46) and Local Dimapur-3 in E4 and E6 (18.45) and (19.69) respectively. While the minimum pod length was found to be in both E2 (9.96) and E3 (9.84) for VRWB-50 followed by E1 (10.29) Local Akuk, VRWB in both E4 (13.63) and E5 (14.05) and in E6 (13.40) VRWB-59. The mean performance for pod length was found maximum in E5 (16.78) followed by E2 (16.61, E6 (16.60), E1 (16.57), E2 (16.440 and E4 (16.02) respectively.

4.8.2.7. Pod Width (cm):

Genotype exhibit maximum (in table 4.17) is found in E3 VRWB-32 (3.52) followed by E2 VRWB-32 (3.50), in E5 (3.40) VRWB-32, E6 (3.27) Local wokha -1, E4 (3.17) VRWB-24 and E1 (3.07) VRWB-116. While minimum has been found in the genotypes E3 (2.10) VRWB-115 followed by E2 and E4 with both (2.20) Local pangti-1 and Local Mongsenyimti, in (2.33) E1 VRWB-112, E1 and E5 (2.33) each with VRWB-112 and Local pangti-2 and E6 with (2.30) Local Suchonoma. The mean performance of the pod width shows maximum findings with E3 (2.69), E4 (2.67), E2 (2.63), E6 (2.63), E1 (2.60) and E5 (2.59).

4.8.2.8. Dry pod weight (g):

The highest dry pod yield (in table 4.17) was shown in the genotype Local Dimapur -3 across all environment *i.e.* E6(7.68), E5 97.64), E4 (7.46), E2 (7.52) and E1 (7.15) except in E2(7.06) by Local Akuk. On the other hand the lowest value was observed in the Local Wokha -1 in all the environment *i.e.* E6 (3.62), E2(3.41), E5 (3.22), E1 (3.11) and E3 (2.96) except for the E4 (3.45) by VRWB-35. The mean performance among all the environment shows highest value in E6 (5.230 followed by E4 (5.070, E5 (5.010E2 (4.96), E1 (4.89) and E3 (4.94).

4.8.2.9. Tuber length (cm):

The highest value (in table 4.18) for the tuber length was observed for the E1 (41.04) followed by E6 (40.41), E3 (40.15), E4 (40.00) VRWB-24 in all three conditions also in E2 (39.95) with NUWB-3 and E3 (36.04) VRWB-54 respectively, on the other hand lowest was observed for the NUWB-1 in all environment *i.e.* E6 (12.83) followed by E3(10.52), E4 (10.46), E5 (10.29), E2 (10.00) and E1 (9.79). The mean performance for the tuber length was observed highest for the E4 (25.44), E6 (25.42), E5 (25.16), E1 (24.06), E2 (23.96) and E3(23.81).

4.8.2.10. Tuber weight (g):

The tuber weight (in table 4.18) exhibits maximum in the VRWB-59 across four environments *viz.* E3 (118.41), E5 (109.48), E2 (107.89) and E1 (102.62, in E6 (104.63) and E4(100.00) VRWB-32 was present. The minimum value was observed for the VRWB-93 in all four conditions E2 (17.64), E3 (18.00), E5(18.19) and (18.45) E6 followed by VRWB-45 in E3 (18.45) and VRWB-75 in E1 (18.98). The mean performance is found to be highest in the E3 (42.67), E2 (42.18), E6 (41.970, E1 (41,64), e6 941.610 and E4 (41.44).

4.8.2.11. Tuber Diameter (cm):

The highest value for the tuber diameter (in table 4.19) was observed for Local Pangti-2 for all the environments *i.e.* E3 (4.50), E2 (4.27), E5 (4.12), E6 (4.10), E4 (3.96) and E1 (3.96). on the other hand, the lowest was observed for VRWB-35 across all the environment *i.e.* E2 (1.20), E3 (1.20), E4 (1.22), E6 (1.22), E1 (1.22) and (1.23). The mean performance for the tuber diameter showed highest performance in E3 (2.61), E5 (2.44), E6 (2.43), E2 (2.43), E4 (2.39) and E1 (2.39).

4.8.2.12. Pod Yield per plant (g):

The genotype exhibit highest pod yield per plant (in table 4.19) is VRWB-17 in E4 (296.29) and E5 (282.14) VRWB-20 across all four conditions E6 (280.22), E2 (259.88), E1 and E3 with (231.82) and (231.31). The lowest seed

yield was found to be in E2 (70.06) Local Baghty followed by NUWB-3 in three environments *i.e.* E3 (91.67), E4 (93.39), E1 (101.00). while Local Baghty showed low performance in E5(100.23), E4 (101.36) and E6 (107.41). The mean performance for the pod yield per plant exhibits highest in E6 (172.46), E3 (172.04), E5 (168.22), E1 (168.07), E4 (164.86), and E1 (160.89).

4.8.2.13. Number of pods per plant:

The highest number of pods per plant (in table 4.20) exhibited in the E2(52.67) and E6 (48.74) with VRWB-36 in both conditions followed by E3 (46.44), E5 (44.83), E4(43.81) and E1 (43.00) with VRWB-17 in all remaining four condition. While the lowest value has been found in the E1(14.67) and E3(17.65) with Local Akuk each and followed by E6 (19.02), E5 (22.50) with Local pangti-2, E2 (22.67) local akuk and E4(23.43) with Local pangti-2. The mean performance of number of pods per plant shows higher in the E2 (38.22) followed by E5 (34.22), E4 (33.98), E6 (30.93) E3 (30.74) and E1 (26.26).

4.8.2.14. Number of seed per pod:

The number of seed (in table 4.20) exhibits highest in the E6 (16.20) VRWB-26, E5 (15.00) VRWB-26, E3 (15.00) Local pangti-1, NUWB-1 in E2 (14.33), E4 (14.00) Local Suchonoma and E1 (13.59) Local Medziphema. The lowest was found in E1 (6.00) VRWB-50 followed by E4 (7.00) Local Akuk E3 (8.00), E2 (8.33), E6 (9.36) and E5 (10.00) VRWB-50 with in rest all conditions. The mean performance of the number of pods per plant is in E1 (10.06) followed by E4 (10.24), E3(12.09), E2 (12.33) E5 (12.64) and E6 (12.65).

4.8.2.15. 100 seed weight (g):

The highest value for the 100 seed weight (in table 4.21) was observed in E2 (42.12) Local Dimapur-2, in E3 (41.87) Local pangti-2 E5(40.54), in E4 (39.99) VRWB-20, in E1 (39.92) Local Dimapur -2 and E6 (28.93) with VRWB-20 respectively. Lowest was found to be in (21.57) E5, E4 (22.37) with VRWB-32, VRWB-50 for three environments *i.e.* E1(23.52), E2 (22.47), E3(25.47) and lastly E6 (28.93) in VRWB-32. The mean performance for the 100 Seed Weight

was highest was found to be in E3(32.24), E2 (31.85), E6(30.60), E5 (30.47), E4 (30.40) and E1 (30.30).

4.8.2.16. Seed Yield per plant (g):

The genotype (in table 4.21) shows maximum value in the environment is E4 (176.31), E1 (175.38) followed by (163.28) E5 and E2 (145.32) all four in VRWB-20 shows dominance and in E3(129.19) with VRWB-17 and E6 (131.00) with VRWB-20. The lowest was observed in the followed by E2 (69.90), E3 (61.33) and E5 (68.00) with Local Pangti-2, in E1 (79.54) and E4 (79.06) with VRWB-32 and lastly lowest in E6 (59.20) also by Local Pangti-2, The mean performance shows highest in E6 (105.03) followed by E5 (104.17), E4 (103.56), E3(97.80), (94.12), E2, E1 (93.30).

4.8.3. Estimation of environmental Index

The ability of an environment to be identify as an ideal test environment is referred to as the discriminating power of an environment (Badu-Apraku *et al.* 2012). From the result (in table 4.22) it is revealed that E₂ (26th March-Summer) (0.586), E₅ (26th March-Summer) (0.239) and E₄ (16th March-Summer) (0.147) was the best sowing date for Plant height and number of pod per plant E₂ (5.824), E₅ (1.832) and E₄ (1.583) whereas, E₁ (6th march Summer) (3.654), E₂ (26th March-Summer) (3.985) and E₃ (6th April-summer) (3.880) was best for days to 50% flowering and Days to first flowering. E₁ (0.848), E₂ (1.227) and E₃ (0.529) which is followed by pod yield per plant E₄ (26th March-Summer) (1.584), E₅ (26th March-Summer) (2.770) and E₄ (16th March-Summer) (4.239) was the best date for this character. For days to pod initiation E₃ (0.833), E₁ (0.548), E₂ (0.7590 and E₅ (0.328) followed by days to maturity E₁ 92.424), E₂ (0.674) and E₅ (0.524) found to be most favourable environments. Pod Length favours best suitable environment for are E₆ (6th April Summer) (0.157), E₁ (0.129), E₂ (0.122) and E₃ (0.171). For seed yield per plant E₁ (15.000) and E₄ (16.659) were most favourable environments. For number of seed per pod four environments viz., E₆ (0.980), E₅ (0.967), E₂ (0.662), and E₃ (0.425) were

the most favourable sowing date. For 100 Seed Weight favourable environments are E₃ (1.140) and E₂ (0.852) as under this environment 100 Seed Weight were effective. For Pod width only E₃ (0.04) was found to be favourable. Followed by Dry pod weight two environment viz., E₆ (0.214) and E₄ (0.054). For Tuber length three environment viz., E₄(0.800), E₆ (0.775) and E₅ (0.515). For Tuber Weight three environment viz., E₃ (0.748), E₂ (0.259) and E₅ (0.054) and for Tuber Diameter only one environment was found favourable i.e., E₃ (0.157).

The environment indices for all the traits under study revealed that none of the trait had positive indices in all the six environments. Mean performance of environments revealed that E₁ and E₄ recorded the least and unfavourable environment for almost all of the characters. When we compare the result of different environments under studied, it clearly showed that E₂ (26th March-*Summer*) was the most favourable environments for maximum number of traits followed by E₃ (6th April-*summer*) and E₆(6th April *summer*) as the favourable sowing date for the different characters. Hence, E₂ (26th March-*Summer*) and E₃ (6th April-*summer*) were considered as the recommended date of sowing in the present study.

Table 4.22: Estimation of environment index (I_j) under different environments

Environmental Index						
Characters	I1	I2	I3	I4	I5	I6
Plant height(m)	-0.775	0.587	-0.248	0.147	0.239	0.050
Days to first Flowering	0.849	1.227	0.529	-0.801	-0.910	-0.894
Days to 50% Flowering	3.655	3.985	3.880	-4.169	-3.920	-3.430
Days to Pod initiation	0.548	0.759	0.833	-1.376	0.329	-1.094
Days to Maturity	2.424	0.675	-1.756	-0.667	0.175	-0.850
Pod Length(cm)	0.129	0.122	0.171	-0.418	-0.162	0.158
Pod Width(cm)	-0.040	-0.019	0.043	-0.019	-0.012	0.045
Dry pod weight (g)	-0.126	-0.052	-0.079	0.054	-0.011	0.214
Tuber length (cm)	-0.579	-0.685	-0.828	0.801	0.515	0.776
Tuber weight (g)	-0.273	0.259	0.748	-0.480	0.054	-0.308
Tuber Width (cm)	-0.058	-0.018	0.158	-0.055	-0.013	-0.015
Pod Yield/plant	-7.330	-0.146	-3.358	3.826	2.770	4.239
Number of pods/plant	-6.134	5.825	-1.648	1.584	1.832	-1.459
Number of seeds/pod	-1.607	0.662	0.426	-1.429	0.968	0.981
100 Seed Weight (g)	-0.465	0.852	1.140	-0.599	-0.528	-0.400
Seed yield/Plant (g)	15.009	-2.760	- 13.373	16.659	-2.350	- 13.185

4.8.4. Stability parameters for individual traits

4.8.4.1. Plant height (m)

The stability parameter (in table 4.23) showed that Plant height (m) ranged from 4.56 m (VRWB-59) to 7.71 m (VRWB-27) with population mean 5.84 m. The 19 genotypes viz., Local Wokha-2, Local Suchonoma, NUWB-4, VRWB-17, VRWB-23, VRWB-24, NUWB-3, VRWB-27, NUWB-1, VRWB-35, VRWB-36, Local Dimapur-1, Local Akuk, Local Dimapur-3, VRWB-77, VRBW-85, VRWB-116 and NUWB-2 had superior value than population mean 5.84 cm, which is desirable.

The 4 genotypes viz., Loal wokha-2, NUWB-1, VRWB-50 and VRWB-23 showed regression coefficient more than 1 NUWB-23 showed regression coefficient less than 1 with non-significant deviation from regression.

Thus, on the basis of stability model in favourable environment ($b_i > \mu$, $b_1 > 1$, NS S²di) 1 genotype NUWB-3 viz., were found to be stable for favourable condition and 4 genotypes viz., Local wokha-2, NUWB-1, VRWB-50 and VRWB-23 were found stable in unfavourable environment ($b_i > \mu$, b_1 , NS, S²di). Whereas, no genotype showed average stability across the environment.

4.8.4.2. Days to first flowering

The stability parameter presented (in table 4.23) revealed that Days to first flowering ranged from 57.89 days VRWB-17 to 152.96 days VRWB-116 with population mean 94.75 days. 19 genotypes viz., VRWB-17, VRWB-20, VRWB-23, VRWB-24, VRWB-26, VRWB-32, VRWB-35, Local Dimapur-1, Local Dimapur-2, Local Akuk, VRWB-50, VRWB-54, VRWB-77, Local Baghty, VRWB-93, VRWB-100, VRWB-112 and VRWB-115, were found inferior than population mean 94.75 days, which is desirable.

The 3 genotypes viz., VRWB-100, VRWB-112 and VRWB-116 exhibited regression coefficient greater than 1, whereas no genotype 5 show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, three genotype viz., VRWB-100, VRWB-112 and VRWB-116 showed their performance for favourable environment ($b_i > 1$, NS S²di) which were to be count stable and no genotypes viz., were stable in unfavorable environment ($b_i < \mu$, $b_1 < 1$, NS, S²di). Whereas, no genotype was found for unity regression which shows average stability across the environments.

4.8.4.3. Days to 50 % flowering

The stability parameter (in table 4.23) revealed Days to 50% flowering ranged from 82.20 VRWB-17 to 152.96 days Local Peren with population mean 125.42 days. 16 genotypes viz., Local Medziphema, VRWB-17, VRWB-20, VRWB-24, Local Pangit-2, Local Dimapur-2, Local Akuk, VRWB-50, VRWB-54, VRWB-77, VRBW-85, Local Baghty, VRWB-93, VRWB-100, VRWB-112

and VRWB-115, were found inferior than population mean 125.42 days, which is desirable.

The 13 genotypes viz., Local Medziphema, VRWB-85, Local baghty, VRWB-17 VRWB-20, VRWB-24, VRWB-50, VRWB-54, VRWB85, VRWB93, VRWB-100, VRWB-112, Local dimapur-2 exhibited regression coefficient greater than 1, whereas 1 genotype viz., VRWB-23 show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, 1 genotype showed their performance for favourable environment VRWB-23 ($b_i > 1$, NS S^2_{di}) which were to be count stable and 13 genotypes viz Local Medziphema, VRWB-85, Local baghty, VRWB-17 VRWB-20, VRWB-24, VRWB-50, VRWB-54, VRWB85, VRWB93, VRWB-100, VRWB-112 and Local dimapur-2 were stable in unfavourable environment ($b_i < \mu$, $b_1 < 1$, NS, S^2_{di}). Whereas, no genotype was found for unity regression which shows average stability across the environments.

Table 4.23: Estimation of stability parameters for Plant height(m), Days to first Flowering and Days to 50% Flowering

Genotypes	Plant height(m)			Days to first Flowering			Days to 50% Flowering		
	Mean	β_i	S ² Di	Mean	β_i	S ² Di	Mean	β_i	S ² Di
LOCAL WOKHA-2	6.42	0.65	0.01	98.31	0.36	4.97**	128.60	0.92	-0.31
LOCAL SUCHONOMA	6.34	0.82	0.02	100.78	6.104*	10.334***	138.30	1.831*	-0.19
NUWB-4	7.14	1.65	0.045*	115.35	-2.328*	4.501**	145.20	2.08	10.090*
LOCAL PEREN	4.71	1.29	0.03	122.45	2.12	-0.16	153.00	1.921*	0.14
LOCAL MEZDIPHEMA	5.61	0.79	0.078**	88.03	1.54	3.657**	121.20	0.83	-1.16
VRWB-17	7.27	1.42	0.203***	57.89	-9.716**	2.643*	82.20	-0.900**	-1.94
VRWB-20	5.70	0.79	0.24***	61.93	-5.492**	-0.43	92.10	0.37	5.32
VRWB-23	6.07	0.98	0.01	77.62	6.287*	7.886***	117.60	2.895**	5.73
VRWB-24	5.86	1.29	0.557***	83.16	-1.75	12.759***	108.70	0.70	1.86
NUWB-3	6.43	1.26	0.01	100.14	6.465**	4.879**	139.80	3.387**	2.47
VRWB-26	5.85	0.48	0.461***	82.96	6.25	16.774***	134.10	2.110*	0.25
VRWB-27	7.41	1.47	0.185***	61.84	-9.980**	3.511**	89.30	-0.158**	0.18
VRWB-68/NUWB-1	6.89	0.90	0.00	110.31	5.416*	7.324***	147.10	2.769**	5.96
VRWB-32	4.78	0.78	0.054*	93.10	2.47	3.081*	131.30	1.36	0.28
VRWB-35	6.28	0.89	0.051*	89.32	-1.31	10.282***	128.60	-0.259*	4.98
VRWB-36	6.86	1.15	0.315***	100.70	0.90	3.262*	137.70	0.83	6.77
LOCAL PANGTI-1	5.67	1.03	0.057*	110.61	-7.172**	11.120***	146.60	1.17	13.759**
LOCAL DIMAPUR-1	6.47	0.91	0.113***	101.90	10.076*	25.295***	136.20	3.095**	-0.35
VRWB-45	5.66	0.76	0.171***	96.72	9.087**	0.46	127.20	3.025*	14.005**
LOCAL PANGIT-2	4.74	1.32	0.053*	122.18	1.53	1.49	146.00	2.130*	9.269*
LOCAL DIMAPUR-2	5.74	1.00	0.147***	82.58	-2.31	8.532***	105.80	0.65	-0.15
LOCAL AKUK	6.62	0.80	0.214***	85.90	-5.891*	11.326***	114.80	-0.08	9.141*
VRWB-50	4.87	1.01	-0.02	94.10	-2.02	17.597***	123.90	-0.059*	1.28
VRWB-54	4.70	1.06	0.02	87.91	0.83	6.476***	114.10	-0.145**	-3.73
LOCAL WOKHA-1	4.62	1.08	0.068**	99.73	-1.21	5.766***	130.30	-0.065**	-2.44
VRWB-59	4.42	1.10	-0.01	112.00	-0.76	7.646***	136.20	0.40	-1.03
LOCAL DIMAPUR-3	7.34	0.62	0.121***	124.69	-2.843*	6.151***	150.30	0.88	5.77
VRWB-75	4.85	1.01	0.00	98.47	10.573*	20.562***	130.50	2.365*	5.41
VRWB-77	6.86	0.40	0.061*	87.10	-0.69	7.615***	113.80	0.12	16.337**
VRBW-85	6.45	0.608*	-0.01	90.58	1.58	2.958*	118.50	-0.057**	-4.44
VRWB-88	5.28	0.84	0.108***	94.87	11.525**	22.635***	126.00	1.654**	-4.66
LOCAL BAGHTY	5.69	0.49	0.03	91.27	5.541*	6.452***	119.70	0.59	-3.36
VRWB-93	5.42	1.03	0.158***	69.86	-2.589*	5.847***	96.20	0.039**	-2.03
VRWB-100	4.92	1.02	0.163***	76.19	-1.948*	0.91	103.50	0.226**	-4.45
VRWB-104	5.47	1.00	0.03	104.62	9.204**	3.494**	132.70	2.469**	1.43
LOCAL MONSENTI	4.66	1.30	0.03	104.44	9.965**	16.545***	130.80	1.17	3.75
VRWB-112	5.43	1.17	0.00	76.44	-1.043*	-0.29	109.80	-0.329**	-0.98
VRWB-115	4.56	1.78	0.106***	88.92	-2.146**	0.72	115.10	-0.166*	9.685*
VRWB-116	6.21	1.21	0.036*	126.30	-2.66	7.041***	150.60	0.40	-0.10
NUWB-2	6.17	0.87	0.036*	118.79	-3.958*	11.543***	143.50	-0.16	20.525***
Mean	5.81	1.00		94.75	1.00		125.40	1.00	
S.E.	0.16	0.34		1.34	1.38		1.30	0.30	

Table 4.24: Estimation of stability parameters for Days to Pod initiation, Days to Maturity and Pod Length(cm)

Genotypes	Days to Pod initiation			Days to Maturity			Pod Length(cm)		
	Mean	β_i	S ² Di	Mean	β_i	S ² Di	Mean	β_i	S ² Di
LOCAL WOKHA-2	101.50	6.973**	-0.90	198.50	0.32	49.348***	17.52	3.43	0.377*
LOCAL SUCHONOMA	108.10	6.589*	1.53	199.30	0.64	24.978**	21.38	9.46	3.713***
NUWB-4	121.20	-0.95	3.87	208.60	0.76	42.551***	16.47	-	-0.07
LOCAL PEREN	126.30	0.68	-5.51	210.80	4.53	195.920***	17.39	2.160**	2.356***
LOCAL MEZDIPHEMA	93.20	2.27	-3.99	207.60	0.97	2.74	19.73	4.89	8.569***
VRWB-17	60.30	-9.190**	-0.76	147.30	-2.12	147.428***	15.77	-	-0.10
VRWB-20	65.30	-4.912**	-3.96	145.50	-0.51	60.720***	19.09	3.705**	0.04
VRWB-23	83.60	6.224**	-1.71	174.20	2.21	89.723***	15.02	4.453*	0.14
VRWB-24	87.10	-2.550*	0.84	154.20	-0.29	15.324*	14.43	2.07	-0.12
NUWB-3	109.30	6.392**	-1.04	214.30	2.67	111.444***	14.52	-0.897*	0.10
VRWB-26	92.20	5.724*	5.39	192.40	-1.09	55.057***	16.12	-0.22	-0.16
VRWB-27	66.60	-6.042**	-4.95	141.70	-0.23	87.745***	13.97	1.27	-0.16
VRWB-68/NUWB-1	113.90	3.76	1.22	197.00	4.47	249.911***	13.97	-	-0.16
VRWB-32	100.30	4.611**	-3.70	182.70	4.45	265.195***	16.57	1.721**	-0.03
VRWB-35	92.50	-3.076**	-4.66	186.60	-1.53	147.022***	16.00	1.07	-0.15
VRWB-36	103.50	-0.40	-3.97	188.10	1.41	20.008**	14.52	1.00	-0.04
LOCAL PANGTI-1	115.90	-7.740**	4.11	206.40	0.03	29.423***	15.06	1.61	-0.12
LOCAL DIMAPUR-1	108.40	8.683**	-3.57	196.60	1.18	-6.33	16.68	1.10	-0.17
VRWB-45	107.50	9.717**	-1.09	192.40	-0.35	23.717**	19.45	1.93	-0.12
LOCAL PANGIT-2	125.00	-0.36	-2.65	199.90	2.31	77.350***	15.15	2.995*	-0.17
LOCAL DIMAPUR-2	84.80	-2.971*	0.67	168.80	-0.64	43.815***	19.39	0.36	0.16
LOCAL AKUK	90.40	-4.246**	-1.29	175.30	0.27	18.244**	19.32	4.235*	0.14
VRWB-50	99.00	-1.880*	-3.32	184.80	0.08	55.434***	13.89	3.91	15.510***
VRWB-54	90.70	0.01	-0.68	162.80	-0.03	26.742**	14.42	-9.83	7.212***
LOCAL WOKHA-1	103.60	-1.33	-2.61	184.40	1.39	6.20	14.87	-8.15	0.6382 **
VRWB-59	114.60	-2.188*	-3.32	186.50	1.78	62.627***	14.77	-1.13	0.17
LOCAL DIMAPUR-3	128.30	-0.87	2.58	194.80	0.65	7.37	13.38	0.126**	-0.19
VRWB-75	104.90	10.150**	6.76	189.00	0.31	3.66	22.12	-4.174*	0.17
VRWB-77	91.90	-1.12	-3.23	170.00	1.68	1.77	16.22	9.00	2.717***
VRBW-85	95.90	2.25	-2.76	174.00	-0.23	13.789*	13.42	-5.99	5.963***
VRWB-88	104.30	9.989*	12.449*	180.20	0.77	-1.05	13.92	-5.548*	1.035***
LOCAL BAGHTY	96.40	4.36	2.24	166.10	2.03	23.906**	14.37	-	-0.07
VRWB-93	71.80	-4.423**	-0.97	148.90	0.34	14.623*	16.22	-	-0.17
VRWB-100	80.80	0.54	-3.89	155.00	0.10	5.49	16.22	1.146**	-0.19
VRWB-104	108.50	6.431**	-4.42	184.60	7.20	90.273***	15.80	0.443**	-0.19
LOCAL MONSENTI	108.70	9.153*	13.285*	180.40	1.53	65.715***	15.77	0.98	-0.08
VRWB-112	79.40	-1.790*	-3.97	156.50	0.80	2.77	18.19	8.83	3.934***
VRWB-115	89.30	-2.974**	-3.84	164.50	0.29	-1.78	18.64	3.72	0.977***
VRWB-116	127.40	-2.864*	-2.39	194.90	1.18	1.65	15.97	3.195**	-0.16
NUWB-2	122.90	-2.630*	-2.91	184.50	0.68	-7.04	15.72	0.76	-0.16
Mean	99.40	1.00		184.50	1.00		15.19	-1.025*	-0.11
S.E.	1.10	1.10		3.50	2.40		14.98	-	-0.12

Table 4.25: Estimation of stability parameters for Pod Width(cm), Dry pod weight (g) and Tuber length (cm)

Genotypes	Pod Width(cm)			Dry pod weight (g)			Tuber length (cm)		
	Mean	β_i	S ² Di	Mean	β_i	S ² Di	Mean	β_i	S ² Di
LOCAL WOKHA-2	2.49	1.91	-0.01	5.35	-1.38	0.121***	30.06	-0.36	7.339***
LOCAL SUCHONOMA	2.39	-1.36	0.00	5.51	1.48	0.088***	22.90	-0.41	0.07
NUWB-4	2.53	-0.03	-0.01	5.03	2.74	0.146***	29.59	0.29	1.383*
LOCAL PEREN	2.51	1.77	0.034***	4.54	-0.45	0.035*	25.52	-1.36	4.438***
LOCAL MEZDIPHEMA	2.51	1.47	0.00	6.51	0.65	0.172***	31.90	-1.587*	1.722*
VRWB-17	2.56	2.10	0.014*	6.44	-0.10	0.123***	20.79	0.66	-0.38
VRWB-20	2.86	5.18	0.049***	6.07	3.48	0.205***	20.23	0.09	0.89
VRWB-23	2.47	-2.16	0.021**	4.76	-0.28	0.290***	34.74	7.582**	0.66
VRWB-24	2.82	-1.78	0.059***	5.83	0.44	0.161***	17.74	0.44	-0.53
NUWB-3	2.44	-0.94	0.01	3.97	1.38	0.131***	38.42	0.09	5.174***
VRWB-26	2.56	1.31	0.01	4.94	0.44	0.195***	21.34	0.30	0.52
VRWB-27	2.49	-2.067**	-0.01	5.49	-1.49	0.085***	10.65	0.80	0.25
VRWB-68/NUWB-1	2.70	2.33	0.069***	4.33	0.69	0.113***	18.14	-0.01	0.58
VRWB-32	3.19	5.64	0.104***	5.96	-1.75	0.212***	22.12	-4.540**	-0.33
VRWB-35	2.60	0.53	0.00	3.99	1.00	0.135***	22.30	2.822*	-0.11
VRWB-36	2.56	-2.807*	0.00	4.39	2.76	0.177***	22.60	0.39	4.845***
LOCAL PANGTI-1	2.54	0.53	0.00	5.32	-0.01	0.151***	31.36	-0.62	2.287**
LOCAL DIMAPUR-1	2.86	3.40	0.00	4.38	0.45	0.045**	17.59	1.58	0.32
VRWB-45	2.66	5.405**	-0.01	5.47	1.31	0.084***	13.14	0.70	-0.07
LOCAL PANGIT-2	2.63	8.10	0.044***	5.35	-1.01	0.188***	22.48	0.93	1.872**
LOCAL DIMAPUR-2	2.85	3.30	0.050***	5.72	-0.73	0.080***	22.93	-0.840*	0.19
LOCAL AKUK	2.59	-0.34	0.0117 *	6.85	2.76	0.102***	25.53	0.57	-0.16
VRWB-50	2.76	6.83	0.0248 **	4.35	-2.479*	0.091***	31.89	-0.08	3.827***
VRWB-54	2.81	9.346*	0.0412***	4.50	3.767*	0.0301 *	33.12	-1.09	1.3098 *
LOCAL WOKHA-1	2.98	3.65	0.011*	3.47	2.47	0.2659***	31.98	1.14	0.35
VRWB-59	2.59	-1.64	0.019**	4.55	0.76	0.0672***	31.52	-0.99	4.7044***
LOCAL DIMAPUR-3	2.70	1.29	0.00	7.57	0.72	0.0706***	24.92	0.19	0.59
VRWB-75	2.75	6.964*	0.00	3.92	0.90	0.0580 **	22.00	-0.06	1.481*
VRWB-77	2.69	-3.48	0.038***	4.08	1.85	0.0311 *	17.55	0.52	-0.48
VRBW-85	2.45	-2.702*	0.00	4.69	-0.92	0.0537 **	23.16	1.74	-0.20
VRWB-88	2.37	-2.091*	0.00	5.37	-0.58	0.091***	31.97	3.72	2.546**
LOCAL BAGHTY	2.55	-0.803*	-0.01	3.68	1.96	0.02	29.92	6.525**	2.742**
VRWB-93	2.52	1.16	0.00	4.80	2.74	0.181***	26.57	5.921*	6.857***
VRWB-100	2.93	-3.82	0.033***	4.93	3.46	0.337***	32.29	2.17	5.216***
VRWB-104	2.67	-2.52	0.103***	5.55	4.333*	0.076***	12.80	0.002*	-0.47
LOCAL MONSENTI	2.45	-0.83	0.016*	4.78	-0.59	0.044**	30.10	5.527**	0.32
VRWB-112	2.65	-3.39	0.094***	4.69	2.92	0.041**	28.85	5.797*	4.747***
VRWB-115	2.55	-2.34	0.037***	4.27	3.757*	0.045**	16.20	-0.07	-0.02
VRWB-116	3.09	1.28	0.00	4.65	1.46	0.085***	15.52	0.53	-0.52
NUWB-2	2.42	1.62	0.016*	4.61	1.08	0.0571**	23.28	1.01	2.138**
Mean	2.64	1.00		5.02	1.00		24.64	1.00	
S.E.	0.08	2.17		0.16	1.35		0.70	0.90	

Table 4.26: Estimation of stability parameters for Tuber weight (g), Tuber Width (cm) and Pod yield per plant

Genotypes	Tuber weight (g)			Tuber Diameter (cm)			Pod yield per plant		
	Mean	β_i	S ² Di	Mean	β_i	S ² Di	Mean	β_i	S ² Di
LOCAL WOKHA-2	31.95	-0.51	1.65	2.97	-1.440*	0.00	201.90	-0.90	407.817**
LOCAL SUCHONOMA	48.27	3.69	1.31	2.40	1.788*	-0.01	163.80	2.965*	10.21
NUWB-4	44.91	-1.92	3.345*	1.52	-0.248*	0.00	170.00	-0.44	275.254**
LOCAL PEREN	49.10	-2.13	4.258**	2.11	1.72	-0.01	200.40	-4.68	758.870**
LOCAL MEZDIPHEMA	30.51	2.54	-0.55	2.24	1.11	0.00	220.40	2.07	59.037*
VRWB-17	35.50	-1.73	1.30	2.07	0.58	0.01	259.40	6.433*	143.074**
VRWB-20	34.76	-1.31	1.58	2.16	0.08	0.017*	255.00	3.84	70.273*
VRWB-23	48.67	3.40	1.99	1.39	1.22	0.00	162.00	2.90	30.95
VRWB-24	25.86	-1.13	0.03	3.48	1.61	0.016*	208.20	3.93	297.641**
NUWB-3	33.64	-1.02	1.42	1.98	1.59	0.013*	108.60	1.94	230.720**
VRWB-26	40.34	3.20	0.49	2.51	0.659*	-0.01	191.00	-2.387*	44.76
VRWB-27	30.49	-0.95	1.06	2.79	0.69	-0.01	203.10	3.773*	53.02
VRWB-68/NUWB-1	58.36	-2.90	7.223***	1.75	-1.38	0.023**	129.30	0.18	13.87
VRWB-32	103.71	9.892*	9.001***	1.21	0.080*	-0.01	167.50	1.99	397.527**
VRWB-35	37.61	-1.17	2.461*	2.00	1.829*	-0.01	138.20	-0.08	441.843**
VRWB-36	27.86	-1.00	0.39	2.36	0.369*	-0.01	181.60	1.59	119.276**
LOCAL PANGTI-1	62.89	5.25	3.550*	2.29	-0.941*	0.00	158.80	2.41	151.466**
LOCAL DIMAPUR-1	48.21	-1.16	5.330**	2.98	1.37	-0.01	144.30	-0.49	123.333**
VRWB-45	19.87	-0.73	-0.55	1.67	2.143*	0.00	191.00	3.20	180.489**
LOCAL PANGIT-2	50.11	3.76	1.70	4.15	2.36	0.00	123.10	-1.04	43.86
LOCAL DIMAPUR-2	23.03	-0.90	-0.15	2.35	0.318*	-0.01	183.80	3.05	47.88
LOCAL AKUK	38.83	-1.95	2.129*	2.40	1.38	0.030**	162.40	1.56	-30.19
VRWB-50	42.02	3.10	0.80	3.06	0.93	0.00	137.80	2.30	-9.75
VRWB-54	51.78	-1.08	7.371***	2.62	1.10	-0.01	130.50	1.48	28.17
LOCAL WOKHA-1	43.88	-2.67	3.6936 **	2.94	2.95	0.047**	131.10	0.30	422.562**
VRWB-59	102.35	24.283*	37.595***	3.19	-0.84	0.01	157.10	0.24	98.829**
LOCAL DIMAPUR-3	25.84	-6.70	34.663***	1.96	2.88	0.027**	219.20	3.35	159.254**
VRWB-75	25.83	6.76	42.495***	2.84	1.45	0.234**	129.00	-0.89	32.26
VRWB-77	28.38	-1.30	0.49	3.24	2.768*	0.00	125.10	1.70	-29.75
VRBW-85	49.36	3.23	2.470*	2.41	1.04	0.00	189.00	2.16	130.230**

VRWB-88	39.67	-1.51	2.4018*	2.05	0.98	0.00	196.9 0	3.59	144.823**
LOCAL BAGHTY	59.39	4.00	3.9606 **	3.29	1.825*	-0.01	107.4 0	-0.23	9.83
VRWB-93	18.53	-0.44	-0.43	2.45	2.794* *	-0.01	156.4 0	-0.12	
VRWB-100	27.70	-0.47	0.72	2.48	0.74	0.412** *	223.4 0	-0.72	10.59
VRWB-104	30.10	2.29	-0.36	1.91	0.10	0.0207 **	153.5 0	0.72	49.72
LOCAL MONSENTI	31.65	-0.93	1.25	2.50	0.80	0.00	137.4 0	-0.978*	7.28
VRWB-112	49.00	-1.05	5.2782 **	3.22	1.22	0.00	165.2 0	1.63	-18.29
VRWB-115	45.06	3.36	1.14	1.69	3.08	0.0155 *	124.8 0	1.56	-11.04
VRWB-116	52.96	-0.45	10.4523** *	2.18	2.052*	0.00	178.5 0	-0.19	20.30
NUWB-2	28.76	-1.67	0.73	3.14	0.10	0.01	142.7 0	-1.791*	2.51
Mean	41.92	1.00		2.24	1.00		168.2 0	1.00	
S.E.	1.15	2.53		0.07	0.93		6.60	1.40	

Table 4.27: Estimation of stability parameters for Number of pods per plant and Number of seeds per pod

Genotypes	Number of pods per plant			Number of seeds per pod		
	Mean	β_i	S ² Di	Mean	β_i	S ² Di
LOCAL WOKHA-2	35.90	0.80	3.829**	11.26	0.198**	-0.22
LOCAL SUCHONOMA	29.02	0.510*	0.50	13.35	0.65	0.34
NUWB-4	31.52	0.447*	1.19	10.36	0.82	0.8894 **
LOCAL PEREN	36.11	0.464*	0.33	11.76	-0.899**	0.8382 **
LOCAL MEZDIPHEMA	33.22	0.58	2.896*	13.18	0.14	1.6768 ***
VRWB-17	44.44	0.41	4.832**	12.86	1.34	0.02
VRWB-20	41.90	0.30	4.417**	13.53	0.89	0.04
VRWB-23	37.73	0.66	7.299***	12.01	0.60	1.610***
VRWB-24	43.00	0.23	8.692***	10.75	0.72	0.25
NUWB-3	24.28	0.52	9.008***	11.76	0.60	0.7001 *
VRWB-26	37.63	0.37	5.606***	13.53	1.24	0.7672 *
VRWB-27	37.51	0.48	3.0248 *	11.74	1.771*	0.14
VRWB-68/NUWB-1	25.96	1.14	-0.62	13.40	1.25	-0.13
VRWB-32	28.41	1.37	4.8608 **	13.53	1.713*	0.06
VRWB-35	31.74	1.45	1.98	11.19	1.45	0.35
VRWB-36	42.45	0.99	45.57***	11.75	0.81	-0.08
LOCAL PANGTI-1	29.18	1.02	11.470***	12.06	0.73	0.937**
LOCAL DIMAPUR-1	26.60	1.32	8.593***	13.52	0.72	0.28
VRWB-45	35.06	1.654*	0.54	11.71	0.70	0.563*
LOCAL PANGIT-2	21.12	0.82	0.10	12.62	1.31	0.24
LOCAL DIMAPUR-2	29.76	0.28	23.272***	10.80	2.145**	-0.06
LOCAL AKUK	20.37	0.81	2.9670 *	8.12	1.14	0.07
VRWB-50	32.57	1.32	1.64	9.42	1.38	0.44
VRWB-54	28.61	1.45	1.62	10.02	1.59	0.18
LOCAL WOKHA-1	33.12	1.874*	4.281**	10.43	1.27	-0.18
VRWB-59	34.01	1.13	-0.18	11.66	1.33	0.29
LOCAL DIMAPUR-3	28.07	1.26	4.899**	12.77	0.67	1.405***
VRWB-75	29.23	1.649*	1.79	12.46	1.610**	-0.25
VRWB-77	26.55	1.14	5.610***	11.71	0.70	0.563*
VRBW-85	37.27	1.800*	5.229**	12.19	2.021*	0.14
VRWB-88	40.48	1.11	10.366***	9.16	0.77	0.623*
LOCAL BAGHTY	23.85	0.99	10.428***	10.42	1.60	0.657*
VRWB-93	30.12	1.37	3.622**	12.69	1.27	1.365***
VRWB-100	38.27	1.25	2.01	11.98	0.61	1.098**
VRWB-104	26.01	0.94	0.02	10.13	0.97	0.609*
LOCAL MONSENTI	31.30	1.32	29.275***	12.41	1.11	-0.04
VRWB-112	36.60	0.93	16.359***	11.25	0.91	0.45
VRWB-115	30.34	1.51	9.314***	10.08	0.031*	0.45
VRWB-116	38.02	1.08	9.202***	10.86	0.96	1.069**
NUWB-2	28.34	1.28	1.40	12.31	1.18	0.7389*
Mean	32.39	1.00		11.67	1.00	
S.E.	1.28	0.32		0.40	0.34	

Table 4.28: Estimation of stability parameters for 100 Seed Weight (g) and Seed yield per plant (g)

Genotypes	100 Seed Weight (g)			Seed yield per plant (g)		
	Mean	β_i	S^2Di	Mean	β_i	S^2Di
LOCAL WOKHA-2	33.05	4.24	15.474***	128.30	1.04	76.482***
LOCAL SUCHONOMA	35.47	-0.682*	0.14	111.30	1.05	102.576***
NUWB-4	36.92	1.86	2.818***	105.90	1.13	14.09
LOCAL PEREN	27.33	4.57	5.454***	91.70	0.58	78.301***
LOCAL MEZDIPHEMA	32.52	-0.06	0.570*	109.60	1.412**	-18.50
VRWB-17	32.41	-1.09	4.441***	140.40	1.48	11.37
VRWB-20	35.98	-3.59	17.535***	152.40	1.62	53.033**
VRWB-23	30.96	1.40	1.284***	117.90	1.583*	2.83
VRWB-24	28.06	4.43	9.336***	98.70	0.48	59.401**
NUWB-3	33.70	-2.183*	2.536***	91.90	1.09	5.56
VRWB-26	34.75	0.36	0.906**	132.50	1.46	68.037**
VRWB-27	30.11	1.21	0.19	111.60	0.63	9.54
VRWB-68/NUWB-1	27.43	1.21	2.584***	77.00	0.536*	-7.20
VRWB-32	26.95	6.19	10.548***	69.80	0.626**	-15.52
VRWB-35	29.41	2.80	1.065***	91.60	0.80	-13.82
VRWB-36	29.14	2.95	2.677***	124.30	1.10	-3.98
LOCAL PANGTI-1	36.48	4.385*	3.249***	108.10	0.97	14.71
LOCAL DIMAPUR-1	38.78	3.05	2.198***	108.40	0.90	-8.79
VRWB-45	28.58	0.01	2.562***	108.50	1.07	-2.58
LOCAL PANGIT-2	32.68	1.04	1.464***	74.00	0.88	-16.66
LOCAL DIMAPUR-2	31.36	2.924*	1.104***	96.70	1.07	-12.06
LOCAL AKUK	28.98	3.98	7.327***	77.60	0.583**	-13.10
VRWB-50	25.09	-0.09	0.778**	78.80	1.10	-10.56
VRWB-54	33.41	-0.22	5.854***	95.70	1.604*	5.47
LOCAL WOKHA-1	25.01	0.49	0.938**	89.80	1.20	14.38
VRWB-59	33.98	0.05	0.11	117.60	0.88	-3.68
LOCAL DIMAPUR-3	30.97	0.64	0.903**	87.60	1.09	-6.10
VRWB-75	31.50	2.29	0.584*	89.50	1.20	-3.87
VRWB-77	27.95	3.64	4.985***	76.10	0.78	-11.84
VRWB-85	29.09	1.50	1.358***	113.70	1.17	-8.23
VRWB-88	30.29	-4.31	21.895***	129.20	1.34	16.36
LOCAL BAGHTY	27.99	0.96	0.886**	80.60	0.64	-3.98
VRWB-93	30.15	-1.97	3.255***	98.20	1.449*	2.19
VRWB-100	29.21	-1.952**	0.17	115.40	0.623*	-9.07
VRWB-104	31.83	0.16	0.04	83.70	1.01	-14.35
LOCAL MONSENTI	30.48	-1.47	4.793***	95.60	0.41	44.880*
VRWB-112	30.73	-1.20	2.189***	109.50	0.85	-3.46
VRWB-115	30.36	0.67	0.933**	86.30	1.16	-6.61
VRWB-116	28.95	0.98	-0.17	112.30	0.73	-5.51
NUWB-2	31.94	0.85	3.707***	98.10	0.670*	-14.59
Mean	31.00	1.00		102.10	1.00	
S.E.	0.89	1.15		2.40	0.20	

4.8.4.4. Days to pod initiation

The stability parameter presented (in table 4.24) revealed that Days to first flowering ranged from 63.22 days VRWB-17 to 128.10 days VRWB-116 with population mean 99.37 days. 19 genotypes viz., Local Medziphema, VRWB-17, VRWB-20, VRWB-27, VRWB-24, VRWB-26, VRWB-32, VRWB-35, Local Dimapur-2, Local Akuk, VRWB-85, VRWB-54, VRWB-77, Local Baghty, VRWB-93, VRWB-100, VRWB-112 and VRWB-115, were found inferior than population mean 99.37 days, which is desirable.

The 4 genotypes viz., Local Medziphema, NUWB-2, VRWB-85 and Local Baghty exhibited regression coefficient greater than 1, whereas 14 genotypes viz., VRWB-17, VRWB-20, VRWB23, VRWB24, VRWB-26, VRWB-35, VRWB-93, VRWB-77, VRWB-112, VRWB-115, Local dimapur-2, Local akuk, VRWB-50, VRWB-54 show regression coefficient more than 1 but no genotypes was found to be regression cpefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, 14 genotype viz., VRWB-17, VRWB-20, VRWB23, VRWB24, VRWB-26, VRWB-35, VRWB-93, VRWB-77, VRWB-112, VRWB-115, Local dimapur-2, Local akuk, VRWB-50 and VRWB-54 showed their performance for favourable environment ($b_i > 1$, NS S^2di) which were to be count stable and no genotypes were stable in unfavourable environment ($b_i < \mu$, $b_1 < 1$, NS, S^2di). Whereas, no genotype was found for unity regression which shows average stability across the environments.

4.8.4.5. Days to maturity

The stability parameter presented in (in table 4.24) revealed that Days to Maturity ranged from (57.89) days VRWB-17 to 152.96 days VRWB-116 with population mean (94.75) days. 16 genotypes viz., VRWB-17, VRWB-20, VRWB-23, VRWB-24, VRWB-27, VRWB-85, VRWB-88, Local Dimapur-2, VRWB-54, VRWB-77, Local Baghty, VRWB-93, VRWB-100, Local

Mongsenyimti, VRWB-112 and VRWB-115, were found inferior than population mean 181.25 days, which is desirable.

The 7 genotypes viz., Local Medziphema, Local dimapur-3, VRWB-88, VRWB-100, VRWB-112, VRWB-115, NUWB-2 exhibited regression coefficient greater than 1, whereas 24 genotypes viz., Local Wokha-2, Local Suchonoma, NUWB-4, VRWB-17, VRWB-20, VRWB-24, VRWB-26, VRWB-27, VRWB-35, Local Pangti-1, VRWB-45, Local Dimapur-2, Local Akuk, VRWB-50, VRWB-54, Local Dimapur-3, VRWB-75, VRWB-85, VRWB-88, VRWB-93, VRWB-100, VRWB-112, VRWB-115 and NUWB-2 shows regression coefficient more than 1 followed by Local dimapur-1, Local wokha-1, VRWB-75, VRWB-77, VRWB-116 shows regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, Local Medziphema, Local dimapur-3, VRWB-88, VRWB-100, VRWB-112, VRWB-115 and NUWB-2 seven genotypes showed their performance for favourable environment ($b_i > 1$, NS S^2_{di}) which were to be count stable and 5 genotypes viz Local dimapur-1, Local wokha-1, VRWB-75, VRWB-77, VRWB-116 were stable in unfavourable environment ($b_i < \mu$, $b_1 < 1$, NS, S^2_{di}). Whereas, no genotype was found for unity regression which shows average stability across the environments.

4.8.4.6. Pod Length (cm)

The stability parameter presented (in table 4.24) revealed that Pod length ranged from 12.76 VRWB-88 to 22.48 Local Dimapur-3 with population mean (16.46). 15 genotypes viz., Local wokha -2, Local Suchonoma, Local peren, Local Medziphema, NUWB-4, VRWB-17, VRWB-20, VRWB-27, VRWB-26, NUWB-1, Local Dimapur-1, VRWB-75, VRWB-100, VRWB-104 and NUWB-2, were found superior than population mean 94.75 days, which is desirable.

The 5 genotypes viz., VRWB-20, Local pangti-1, Local dimapur-1, Local pangti-2 and Local dimapur-2 exhibited regression coefficient greater than 1,

whereas 8 genotypes viz., NUWB-4, and Local wokha-1 show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, 2 genotypes NUWB-4 and Local wokha-1 showed their performance for favourable environment ($b_i=1$, NS S^2_{di}) which were to be count stable and 5 genotypes viz VRWB-20, Local pangti-1, Local dimapur-1, Local pangti-2 and Local dimapur-2 were stable in unfavourable environment ($b_i < \mu$, $b_1 < 1$, NS, S^2_{di}). Whereas, one genotype NUWB-1 ($b_i=1.06$, $S^2_{di}= -0.031$) was found for unity regression which shows average stability across the environments.

4.8.4.7. Pod Width (cm)

The stability parameter presented (in table 4.25) revealed that Pod Width ranged from (2.33) VRWB-85 to (3.19) VRWB-32 with population mean (2.65). 12 genotypes viz., VRWB-20, VRWB-24, VRWB-27, VRWB-85, VRWB-88, Local Dimapur-2, VRWB-54, VRWB-75, VRWB-77, VRWB-100, VRWB-104 and VRWB-116, were found superior than population mean 2.63, which is desirable.

The no genotypes viz., exhibited regression coefficient greater than 1, whereas 18 genotypes viz Local dimapur-1, VRWB-45, Local dimapur-3, VRWB-75 and VRWB-116 show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, no genotypes showed their performance for favourable environment ($b_i > 1$, NS S^2_{di}) which were to be count stable and five genotypes Local dimapur-1, VRWB-45, Local dimapur-3, VRWB-75 and VRWB-116 were stable in unfavourable environment ($b_i < \mu$, $b_1 < 1$, NS, S^2_{di}). Whereas, one genotype VRWB-116 ($b_i=1.12$, $S^2_{di}= 0.002$) was found for unity regression which shows average stability across the environments.

4.8.4.8. Tuber Weight (g)

The stability parameter for Number of pods per plant (in table 4.26) in showed ranged from 18.53 VRWB-93 to 103.76 VRWB-32, with population mean (41.91). 18 genotypes viz., Local Suchonoma, NUWB-4, Local Peren, VRWB-23, NUWB-1, VRWB-32, Local Pangti-1, Local Dimapur-1, Local Pangit-2, VRWB-50, VRWB-54, Local wokha-1, VRWB-59, VRWB-85, Local Baghty, VRWB-112, VRWB-115 and VRWB-116, were found superior than population mean, which is desirable.

The 4 genotypes viz., Local Suchonoma, VRWB-23, VRWB-26, Local Pangti-2, and VRWB-115 exhibited regression coefficient greater than 1, whereas no genotypes showed regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, four genotypes viz Local Suchonoma, VRWB-23, VRWB-26, Local Pangti-2, and VRWB-115 showed their performance for favourable environment (b_i1 , NS S^2di) which were to be count stable and no genotypes were stable in unfavourable environment ($b_i < \mu$, $b_i1 < 1$, NS, S^2di). Whereas, no genotype was found for unity regression which shows average stability across the environments.

4.8.4.9. Dry pod weight (g)

The stability parameter for Number of pods per plant (in table 4.25) showed ranged from 7.57 Local Wokha-1 to 3.47 Local Dimapur-3, with population mean (5.01). 17 genotypes viz., Local wokha-2, Local Suchonoma, NUWB-4, Local Medziphema, VRWB-17, VRWB-20, VRWB-24, VRWB-27, VRWB-32, Local Pangti-1, VRWB-45, Local Pangit-2, Local Dimapur-2, Local Akuk, Local Dimapur-3, VRWB-88, and VRWB-104 were found superior than population mean, which is desirable.

The no genotypes exhibited regression coefficient greater than 1, also no genotypes exhibited and showed regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, no genotype showed their performance for favourable environment ($b_i > 1$, NS S^2_{di}) which were to be count stable at the same time no genotypes were stable in unfavourable environment ($b_i < \mu$, $b_i < 1$, NS, S^2_{di}). Whereas, no genotype was found for unity regression which shows average stability across the environments.

4.8.4.10. Tuber Length (g)

The stability parameter for Number of pods per plant presented (in table 4.25) revealed that ranged from 10.65 VRWB-17 to 38.42 NUWB-3, with population mean (24.64). 19 genotypes viz., Local wokha-2, NUWB-4, Local Peren, Local Medziphema, VRWB-23, NUWB-3, Local Pangti-1, VRWB-50, VRWB-54, Loal Wokha-1, VRWB-59, Local Akuk, Local Dimapur-3, VRWB-88, Local Baghty, VRWB-93, VRWB-100, Local Mongsenyimti, and VRWB-112 were found superior than population mean, which is desirable.

The 1 genotype viz., VRWB-23 exhibited regression coefficient greater than 1, whereas 2 genotypes viz., Local akuk and Local Dimapur-3 show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on basis of stability model, one genotypes viz., VRWB-23 showed their performance for favourable environment ($b_i > 1$, NS S^2_{di}) which were to be count stable and two genotypes viz Local Akuk and local Dimapur-3 were stable in unfavourable environment ($b_i < \mu$, $b_i < 1$, NS, S^2_{di}). Whereas, one genotype Local Wokha-1 ($b_i = 1.14$, $s^2_{di} = 0.35$) was found for unity regression which shows average stability across the environments.

4.8.4.11. Tuber Diameter(g)

The stability parameter for Number of pods per plant (in table 4.26) revealed ranged from 1.21 Local Pangti-2 to 4.14 VRWB-32, with population

mean (2.45). 17 genotypes viz., Local wokha-2, VRWB-27, VRWB-24, VRWB-26, Local Dimapur-1, Local Pangti-2, VRWB-50, VRWB-54, Local wokha-1, VRWB-59, VRWB-75, VRWB-77, Local Bagthy, Local Mongsenyimti, VRWB-100, VRWB-112 and NUWB-2, were found superior than population mean, which is desirable.

The 6 genotype viz., VRWB-77, Local bagthy, VRWB-93, VRWB112, Local suchonoma and Local Dimapur-1 exhibited regression coefficient greater than 1, whereas 11 genotypes viz., Local wokha-2, VRWB-26 VRWB-27, VRWB-36, VRWB-59, Local Mongsenyimti, NUWB-2 Local Pangti-1, Local Pangti-2, Local Dimapur-2, and VRWB-50 show regression coefficient less than 1 along with non-significant deviation from the regression.

Thus, on the basis of stability model, six genotype VRWB-77, Local bagthy, VRWB-93, VRWB112, Local suchonoma and Local Dimapur-1 showed their performance for favourable environment ($b_i > 1$, NS $S^2 di$) which were to be count stable and eight genotypes viz Local wokha-2, VRWB-26 VRWB-27, VRWB-36, Local Pangti-1, Local Pangti-2, VRWB-59, Local Mongsenyimti, NUWB-2, Local Dimapur-2, and VRWB-50, were stable in unfavourable environment ($b_i < \mu$, $b_i < 1$, NS, $S^2 di$). Whereas, one genotype Local Medziphema ($b_i = 1.10^*$, NS, $S^2 di = 0.018$), VRWB-54 ($b_i = 1.10$, $s^2 di = -0.01$) and VRWB-85 ($b_i = 1.01^*$, $s^2 di = 0.02$) was found for unity regression which shows average stability across the environments.

4.8.4.12. Pod yield per plant (g)

The stability parameter (in table 4.26) showed that Pod yield per plant ranged from 107.40 Local Bagthy to 259.39 VRWB-17 with population mean (168.21). 15 genotypes viz., Local wokha -2, Local Suchonoma, Local peren, Local Medziphema, NUWB-4, VRWB-17, VRWB-20, VRWB-27, VRWB-26, NUWB-1, Local Dimapur-1, VRWB-75, VRWB-100, VRWB-104 and NUWB-2, were found superior than population mean, which is desirable.

The 3 genotypes viz., VRWB-26, VRWB-100 and VRWB-115 exhibited regression coefficient greater than 1, whereas 16 genotypes viz., VRWB-27 and Local Dimapur-3 show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, 3 genotype VRWB-26, VRWB-100, VRWB-115 and Local Medziphema showed their performance for favourable environment ($b_i > 1$, NS, S^2_{di}) which were to be count stable and 2 genotypes viz VRWB-27 and Local Dimapur-3 were stable in unfavourable environment ($b_i < \mu$, $b_1 < 1$, NS, S^2_{di}). Whereas, no genotype was found for unity regression which shows average stability across the environments.

4.8.4.13. Number of pods per plant

The stability parameter for Number of pods per plant presented (in table 4.27) revealed that ranged from 20.84 Local Akuk to 44.13 VRWB-17, with population mean (16.46). 18 genotypes viz., Local wokha -2, Local peren, Local Medziphema, VRWB-17, VRWB-20, VRWB-24, VRWB-27, VRWB-26, NUWB-1, VRWB-27, VRWB-32, VRWB-36, VRWB-45, Local Dimapur-2, Local Dimapur-3, VRWB-85, VRWB-88, and VRWB-100 were found inferior than population mean, which is desirable.

The 4 genotypes viz., VRWB-45, VRWB-50, VRWB-59, VRWB-100 exhibited regression coefficient greater than 1, whereas 1 genotype viz., Local peren show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, four genotype viz., VRWB-45, VRWB-50, VRWB-59, VRWB-100 showed their performance for favourable environment ($b_i > 1$, NS, S^2_{di}) which were to be count stable and one genotypes viz Local peren were stable in unfavourable environment ($b_i < \mu$, $b_1 < 1$, NS, S^2_{di}). Whereas, two genotypes VRWB-59 ($b_i = 1.01^*$, NS, $S^2_{di} = 10.36$) was found for unity regression which shows average stability across the environments.

4.8.4.14. Number of seeds per pod

The stability parameter for Number of pods per plant presented (in table 4.27) showed that ranged from 20.84 Local Akuk to 44.13 VRWB-17, with population mean (32.39). 25 genotypes viz., Local Suchonoma , Local Peren , Local Medziphema , VRWB-17, VRWB-20, VRWB-23, NUWB-3, VRWB-26, VRWB-27, NUWB-1, VRWB-32, VRWB-36, Local Pangti-1, Local Dimapur-1, VRWB-45, Local Pangit-2, VRWB-59, Local Dimapur-3, VRWB-75 VRWB-77, VRBW-85, VRWB-88, Local Baghty, VRWB-93, VRWB-100, VRWB-104 and Local Mongsenyimti, were found inferior than population mean, which is desirable.

The 4 genotypes viz., Local Mongsenyimti, VRWB-20, VRWB-36, Local pangti-2 and Local dimapur-1, exhibited regression coefficient greater than 1, whereas 12 genotypes viz., VRWB-17, VRWB-27, NUWB-1 and VRWB-32. show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, four genotype viz., Local Mongsenyimti, VRWB-20, VRWB-36, Local pangti-2 and Local dimapur-1, showed their performance for favourable environment (b_i1 , NS S^2di) which were to be count stable and four genotypes viz., VRWB-17, VRWB-27, NUWB-1 and VRWB-32, were stable in unfavourable environment ($b_i < \mu$, $b_{i1} < 1$, NS, S^2di). Whereas, one genotype Local Mongsenyimti ($b_i = 1.10^*$, NS, $S^2di = -0.04$) was found for unity regression which shows average stability across the environments.

4.8.4.15. 100 Seed Weight (g)

The stability parameter for Number of pods per plant presented (in table 4.28) showed that ranged from 24.78 VRWB-50 to 38.45 Local Dimapur-1, with population mean (30.71). 20 genotypes viz., Local wokha-2, Local Suchonoma, NUWB-4, Local Medziphema, VRWB-17, VRWB-20, VRWB-23, NUWB-3, VRWB-26, Local Pangti-1, Local Dimapur-1, Local Pangit-2, Local Dimapur-

2, VRWB-54, Local wokha-1, VRWB-59, Local Dimapur-3, VRWB-75, VRWB-104 and NUWB-2, were found superior than population mean, which is desirable.

The no genotypes exhibited regression coefficient greater than 1, whereas 3 genotypes viz., Local Suchonoma, VRWB-59 and VRWB-104 show regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, four genotype Local Wokha-2, NUWB-4, Local Dimapur-1 and Local Dimapur-3 showed their performance for favourable environment (b_1 , NS S^2d_i) which were to be count stable and three genotypes viz Local Suchonoma, VRWB-59 and VRWB-104 were stable in unfavourable environment ($b_1 < \mu$, $b_1 < 1$, NS, S^2d_i). Whereas, no genotypes were found for unity regression which shows average stability across the environments.

4.8.4.16. Seed yield per plant (g)

The stability parameter for seed yield per plant presented (in table 4.28) showed that the ranged from 66.17 Local Akuk to 150.90 VRWB-20, with population mean (99.66). 20 genotypes viz., Local wokha-2, Local Suchonoma, NUWB-4, Local Medziphema, VRWB-17, VRWB-20, VRWB-23, VRWB-26, VRWB-27, VRWB-36, Local Pangti-1, Local Dimapur-1, VRWB-45, Local Pangit-2, VRWB-59, VRWB-85, VRWB-88, VRWB-100, VRWB-112 and VRWB-116 were found superior than population mean, which is desirable.

The 6 genotypes viz., NUWB-4, Local Medziphema, VRWB-17, VRWB-23, VRWB-36 and VRWB-88 exhibited regression coefficient greater than 1, whereas 5 VRWB-27, VRWB-59, VRWB-100, VRWB-105 and VRWB-116 genotypes viz., how regression coefficient less than 1 along with non-significant deviation from regression.

Thus, on the basis of stability model, six genotype NUWB-4, Local Medziphema, VRWB-17, VRWB-23, VRWB-36 and VRWB-88 showed their

performance for favourable environment ($b_i > \mu$, NS S^2d_i) which were to be count stable and five genotypes viz Local Suchonoma, VRWB-27, VRWB-59, VRWB-100, VRWB-105 and VRWB-11 were stable in unfavourable environment ($b_i < \mu$, $b_i < 1$, NS, S^2d_i). Whereas, four genotype VRWB-36, Local Pangti-1, Local Dimapur-1 and NUWB-4 was found for unity regression which shows average stability across the environments.

4.9. Pooled Analysis of variance based on AMMI model.

The pooled analysis of variance for sixteen different traits based on the AMMI model is depicted in Table 4.29. The mean squares due to genotypes, environment as well as G x E interaction was highly significant for all the traits and G x E was further partitioned into three principal components; PC I, PC II, PC III, PC IV and PC V were highly significant for all the traits and the residual SS of AMMI were non-significant for all the traits.

The per cent contribution of genotypic main effect ranged from 44.62 % (Number of seeds per pod) to 97.40 % (Tuber weight) of the total variation (Table 4.26). The environment per cent contribution ranged from 0.25 % (Days to first Flowering, Days to Pod initiation) to 31.26 % (Number of seeds/pod) of the variation. The G x E interaction varied from 2.55 % (Tuber weight) to 34.16 % (100 Seed Weight) of the total variation and accounted for a large percentage of SS for plant height. The first PC components explained 41.38 % (Number of pods/plant) to 91.67 % (Pod Length) of G x E sum of squares. The second PC components explained between 5.85 % (Days to first Flowering) to 34.97 % (Number of seeds/pod) of interaction SS. The mean squares for the PC 1 and PC2 cumulatively contributed greater than 55 % of the total G x E interaction for all the traits.

4.9.1. Phenotypic stability analysis based on AMMI and GGE biplot for seed yield per plant (G)

To investigate the main effects and interactions across different environments, AMMI1 and AMMI2 biplot was constructed for seed yield per plant. AMMI1 biplot of main effects (genotypes and environments) are shown

along the abscissa and the ordinate represents the first PC. The interpretation of a biplot assay is that if main effects have PC score close to zero, it indicates negligible interaction effects and when a genotype and an environment have the same sign on the PC axis, their interaction is positive; if different, their interaction is negative. The PC1 versus PC2 biplot (i.e., AMMI 2 biplot), explains the magnitude of interaction of each genotype and environment. The genotypes and environments that are farthest from the origin being more responsive fit the worst. Genotypes and environments that fall into the same sector interact positively; negatively if they fall into opposite sectors (Anandan *et al.* 2009).

Table 4.29: AMMI ANOVA of forty-winged bean genotypes for sixteen characters pooled over six environments

Source of variation	ENV	REP(ENV)	GEN	ENV X GEN	PC1	PC2	PC3	PC4	PC5	Residuals
DF	5	12	39	195.00**	43.00**	41.00**	39.00**	37.00**	35.00**	480
Plant height(m)	26.12**	26.11	13.65**	0.37**	0.88**	0.36**	0.32**	0.11**	0.09**	0.08
Days to first Flowering	114.59**	3.82	5289.61**	109.60**	428.58**	30.49**	24.15**	19.39**	0.93**	4.35
Days to 50% Flowering	2131.44**	26.68	5662.43**	91.17**	320.96**	46.18**	34.56**	18.20**	1.77**	16.16
Days to Pod initiation	114.48**	28.19	5395.39**	90.20**	363.01**	28.90**	15.49**	3.99**	1.20**	19.36
Days to Maturity	277.87**	13.16	6724.34**	176.86**	586.24**	102.50**	75.16**	57.10**	0.97**	22.46
Pod Length(cm)	6.89**	0.55	88.09**	7.49**	31.15**	2.23**	0.43**	0.23**	0.14**	0.60
Pod Width(cm)	0.16**	0.34	0.66**	0.11**	0.23**	0.12**	0.06**	0.05**	0.03**	0.02
Dry pod weight (g)	1.77**	0.04	14.21**	0.46**	0.95**	0.41**	0.36**	0.29**	0.20**	0.05
Tuber length (cm)	71.97**	1.89	811.21**	16.43**	48.86**	17.88**	4.91**	3.05**	1.85**	2.35
Tuber weight (g)	24.72**	6.08	5907.60**	30.93**	75.61**	35.52**	21.25**	11.43**	2.03**	4.54
Tuber Width (cm)	0.77**	0.02	7.02**	0.10**	0.28**	0.13**	0.02**	0.00**	0.00**	0.02
Pod Yield/plant	2652.32**	62.34	25595.56**	702.61**	1947.44**	526.17**	509.57**	245.63**	78.10**	91.99
Number of pods/plant	1974.14**	4.46	654.32**	30.06**	56.41**	47.16**	23.06**	13.90**	2.54**	4.48
Number of seeds/pod	171.42**	0.75	31.37**	3.39**	7.63**	5.64**	1.54**	0.83**	0.32**	1.01
100 Seed Weight (g)	72.37**	0.75	179.83**	19.62**	56.19**	4.79**	1.81**	1.22**	0.82**	0.82
Seed yield/Plant (g)	20846.76**	14.37	6684.84**	128.14**	307.15**	132.50**	67.79**	62.18**	40.07**	59.01

Table 4.30: Per cent contribution of each component to the total variation

Source of variation	ENV	GEN	ENV X GEN	PC1	PC2	PC3	PC4	PC5
Plant height(m)	17.77	72.44	9.78	52.38	20.42	17.10	5.88	4.21
Days to first Flowering	0.25	90.39	9.36	86.23	5.85	4.41	3.36	0.15
Days to 50% Flowering	4.28	88.59	7.13	77.63	10.65	7.58	3.79	0.35
Days to Pod initiation	0.25	92.06	7.69	88.75	6.74	3.43	0.84	0.24
Days to Maturity	0.47	87.97	11.57	73.09	12.18	8.50	6.13	0.10
Pod Length(cm)	0.70	69.67	29.63	91.67	6.26	1.15	0.58	0.34
Pod Width(cm)	1.64	52.69	45.67	49.32	23.52	11.82	8.35	5.28
Dry pod weight (g)	1.36	84.93	13.71	45.52	18.78	15.82	12.13	7.76
Tuber length (cm)	1.02	89.88	9.10	65.60	22.89	5.98	3.52	2.02
Tuber weight (g)	0.05	97.40	2.55	53.91	24.15	13.75	7.01	1.18
Tuber Width (cm)	1.29	92.44	6.27	65.27	29.29	5.15	0.26	0.03
Pod Yield/plant	1.15	86.92	11.93	61.12	15.75	14.51	6.63	2.00
Number of pods/plant	23.93	61.86	14.21	41.38	32.99	15.34	8.77	1.52
Number of seeds/pod	31.26	44.62	24.11	49.61	34.97	9.10	4.67	1.67
100 Seed Weight (g)	3.23	62.61	34.16	87.14	7.09	2.54	1.63	1.03
Seed yield/Plant (g)	26.73	66.86	6.41	52.86	21.74	10.58	9.21	5.61

4.9.1.1. Seed yield per plant (g)

AMMI analysis of variance for Seed yield per plant showed that 26.73 % of the total sum of squares revealed to the environmental effects, 66.86 % to genotypic effects, and 6.41 % to GEI effects (Table 4.30). The first principal component (PCI) of the interaction captured 52.86 % of the interaction sum of squares. Similarly, the second principal component axis (PCII) explained a further 21.74% of the GEI sum of squares and cumulatively contributed to 74.60 % of the total GEI. Both AMMI1 and AMMI2 biplot analysis was performed for Seed yield per plant since mean squares for the PC1 and PC2 were found to be significant.

AMMI1 biplot analysis for Seed yield per plant showed that relative variability due to genotypes was high than the variability due to most of the environments as indicated by the distribution as well as position occupied by the forty genotypes and four environments on biplot display (Fig 4.21). Genotypes or environments on right hand side of the vertical line (mid value) showed higher value of Seed yield per plant than those on the left-hand side. Thus, 19 out of 40

genotypes namely, VRWB-20 (G7), VRWB-17 (G6), VRWB-26(G11),VRWB-88 (G31), Local wokha-2 (G1), VRWB-36 (G16), VRWB-23 (G8),VRWB-59 (G26), G34,VRWB-85 (G30),VRWB-116 (G39), (G12) VRWB -27, Local Suchonoma (G2), (G5) Local Medziphema,VRWB-112 (G37),VRWB-45 (G19), Local Dimapur-1 (G18), Local Pangti-1(G17) and (G3) NUWB-4 were exhibited higher grain yield, among them G7 being the overall best with general mean of 152.40 but among these genotypes Local Pangti-1 (G17), NUWB-1 (G3) and Local Dimapur-1 (G18) , had shown stable performance in respect of Seed yield per plant due to its position near to origin indicating suitable for getting highest Seed yield per plant in range of environments. Among the test environments, two out of six environments namely, E1 and E4 occupied position on the right-hand side of the midpoint of the main effect axis and below average environmental performance seems to be most favourable environments in respect of grain yield. Similarly, the environment E5 had lower mean value and below average environmental performance in respect of grain yield per plant, so judged as the poor environments for grain yield per plant.

Genotypes or environments with larger negative or positive PC1 scores have high interactions, while those with PC1 scores near zero (close to horizontal line) have little interaction across environments. Only one genotype, G9 fell near the horizontal line indicating their uniform performance across the environments. However, it is to mention that four genotypes namely Local Pangti-1 (G17), G3 andVRWB-93 (G33), were close to PC1 axis and also placed near to midpoint axis of main effect and therefore considered to be stable against the environmental changes with minor positive and negative interactions.

AMMI2 biplot (Fig. 4.22) where environment with short spoke/vector do not exert strong interaction or exert weak interaction, whereas, those with long spoke/vector exerted strong interaction. E3, E4 and E5 had short spoke and they did not exert strong interaction while environment E1, E2 and E6 had long spoke/vector exerted strong interaction.

From the polygon view of AMMI2 biplot (Fig. 4.23), the outer genotype Local Mongsenyimti (G36), VRWB-24 (G9), Local Peren(G4), Local Suchonoma (G2), (G24) VRWB-54, VRWB-20 (G7), VRWB-26 (G11) and VRWB -27 (G12), were connected, analysis for Seed yield/plant showed genotype Local Mongsenyimti (G36), excel “winner genotype” in performance in E2 and E3. The genotypes near origin VRWB-50 (G23), Local pangti-2 (G20), Local Dimapur-1 (G18), and Local dimapur-2 (G21) were less or non-sensitive to environmental condition.

4.9.1.2. Winning Genotype and Mega- Environments

Representation of the which-won-where example of MET information is significant for considering the possible presence of various mega conditions is presented in Fig. 4.24. The polygon of lines in Figure 4.25 is made by associating vertex genotypes; by interfacing straight lines and the remainder of genotypes fall inside the polygon. The vertex genotypes in this investigation were VRWB-54 (G24), Local pangti-2 (G20), VRWB-32 (G14), NUWB-1 (G13), Local Mongsenyimti (G36), Local wokha-2 (G1) and G7 (Fig. 4.25). These genotypes have the largest vectors in their respective directions; the vector length and direction represent the extent of the response of the genotypes to the tested environments. All other genotypes are contained within the polygon and have smaller vectors, i.e., they are less responsive in relation to the interaction with the environments within that sector. These genotypes are either the best or least fortunate genotypes in a few or all conditions since they are farthest from the beginning. In the present study of the GGE biplot investigation of the forty-winged bean genotypes assessed at four conditions revealed that the initial two principal components possessed 95.97% of the absolute fluctuation (Fig. 4.25).

Which-won-where identified the best winner genotypes for the mega environment. This suggests that the genotypes can be determined and fixed in such small mega-environments. Information on the prevalence of Seed yield per plant may be obtained by this. As a result of the biplot analysis, Fig. 4.25

suggests only one super condition. In this mega-environment all environments E1, E2, E3, E4, E5 and E6 included and the winning genotype is G7.

4.9.1.3. The relationship among test Environments

The interrelationship among the environments is presented in the vector view of the GGE-biplot (Fig. 4.26). The angle between the environment vectors provides further information on the correlation between environments, where an acute angle indicates a positive correlation, an obtuse angle indicates negative correlation and a right angle indicates no correlation (Fig. 4.26). Accordingly, all environments were positively correlated except E2, E3 and E6 as all of the angles among them were smaller than 90° suggesting that indirect selection for Seed yield per plant can be practical across these test environments. The difference between the average yield of genotypes VRWB-77 (G29), Local pangti-2 (G20) and VRWB-32 (G14), were lowest in all environments i.e., they contributed less to the GE interaction. That is to say that a genotype adaptable or with good performance in one environment may exhibit a similar response in another environment more correlated to it.

4.9.1.4. Discriminativeness vs. Representativeness

A line that passes across the biplot source and average condition (shown by a small circle) is called the Average Environment Coordinate (AEC). A testing environment that shares certain information with the AEC is becoming more representative of other testing environments. As a result, genotype evaluation in the E1 environment increased the observed genotypic variation between genotypes for seed yield/plant of tested genotypes of winged bean (Fig. 4.27). The vector length and angle with the origin clearly show that environments E1, E5 and E6 were the most discriminative. Thus, it may be concluded that E2 and E4 is the greatest representation of all environments, followed by E3.

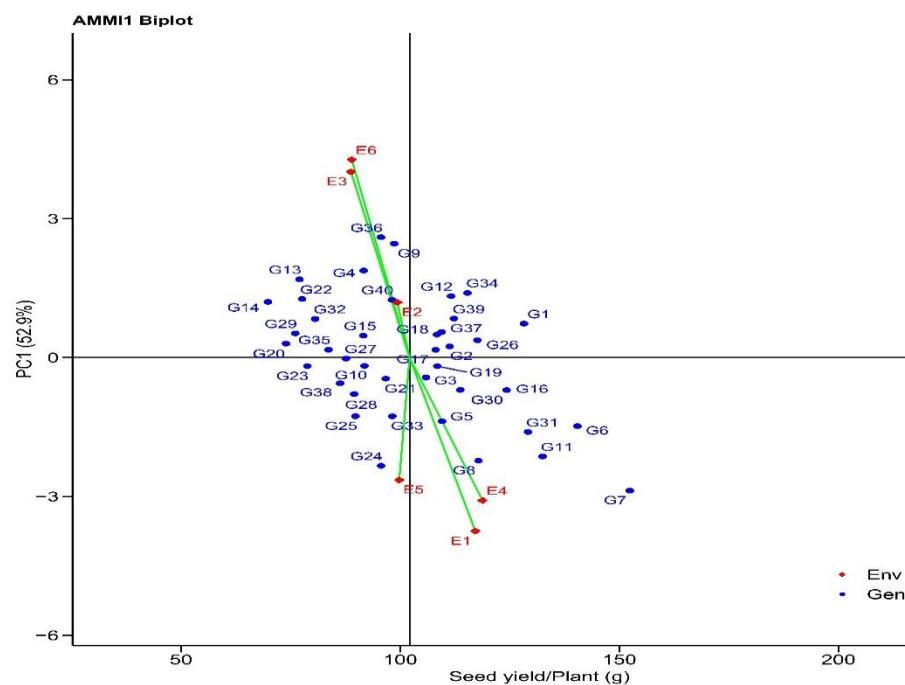


Fig. 4.21: AMMI1 biplot of main effects and G x E interaction of forty-winged bean genotypes for the character Seed yield per plant

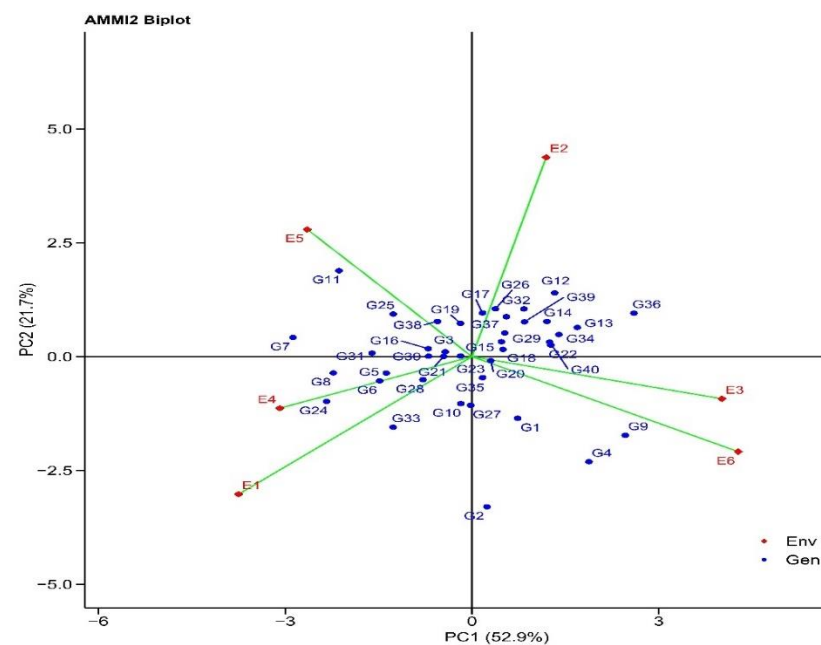


Fig. 4.22: AMMI2 biplot of main effects and G x E interaction of forty-winged bean genotypes for the character Seed yield per plant

G1	LOCAL WOKHA-2	G9	VRWB-24	G17	LOCAL PANGTI-1	G25	LOCAL WOKHA-1	G33	VRWB-93
G2	LOCAL SUCHONOMA	G10	NUWB-3	G18	LOCAL DIMAPUR-1	G26	VRWB-59	G34	VRWB-100
G3	NUWB-4	G11	VRWB-26	G19	VRWB-45	G27	LOCAL DIMAPUR-3	G35	VRWB-104
G4	LOCAL PEREN	G12	VRWB-27	G20	LOCAL PANGIT-2	G28	VRWB-75	G36	LOCAL MONSENTI
G5	LOCAL MEZDIPHEMA	G13	VRWB-68	G21	LOCAL DIMAPUR-2	G29	VRWB-77	G37	VRWB-112
G6	VRWB-17	G14	VRWB-32	G22	LOCAL AKUK	G30	VRWB-85	G38	VRWB-115
G7	VRWB-20	G15	VRWB-35	G23	VRWB-50	G31	VRWB-88	G39	VRWB-116
G8	VRWB-23	G16	VRWB-36	G24	VRWB-54	G32	LOCAL BAGHTY	G40	NUWB-2

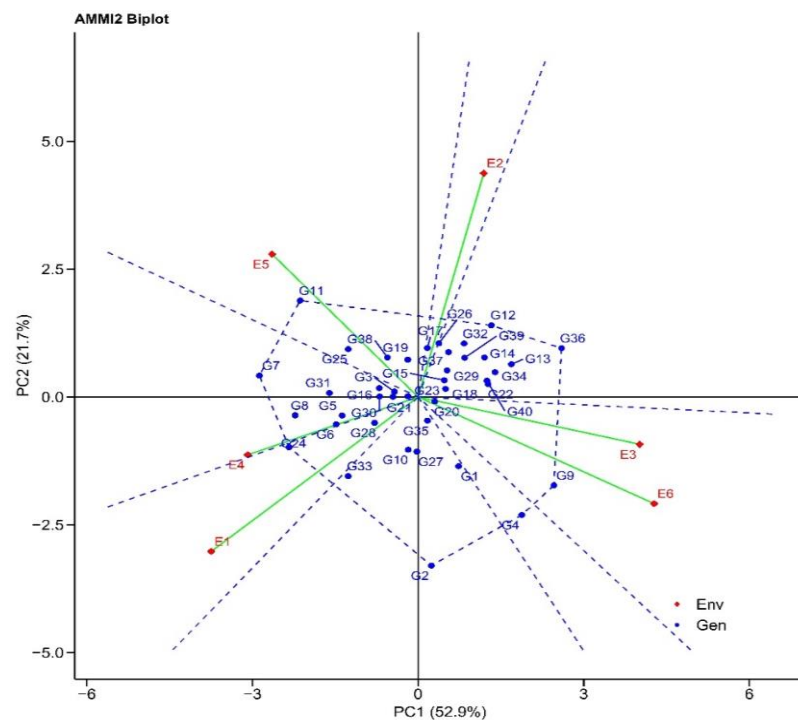


Fig. 4.23: AMMI2 “polygon view” biplot of main effects and G x E interaction of forty winged bean genotypes for the character Seed yield per plant

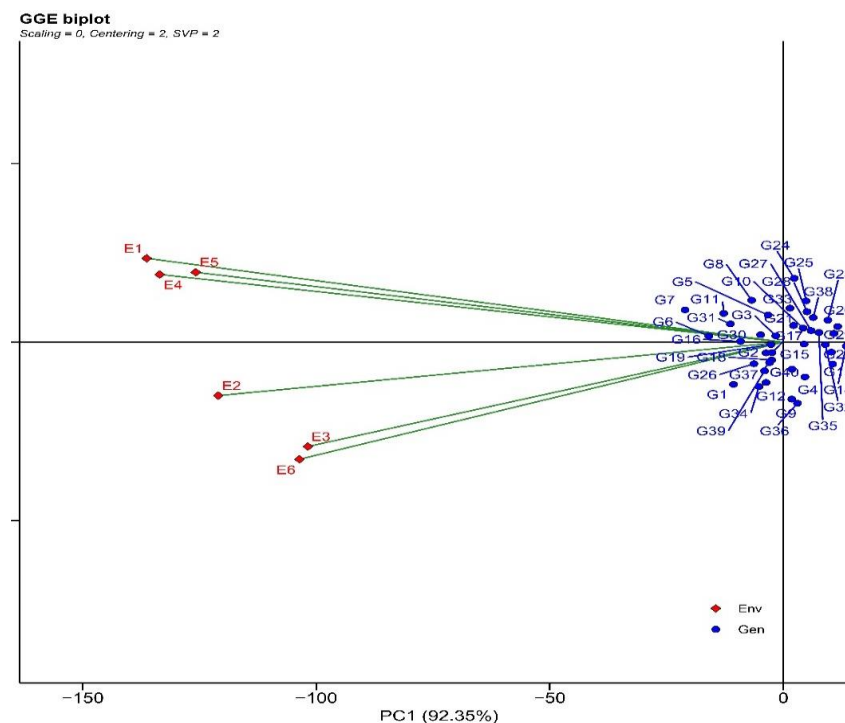


Fig. 4.24: The environment vector perspective of the GGE biplot illustrates the resemblances among test environments for Seed yield per plant

G 1	LOCAL WOKHA-2	G9	VRW B-24	G1 7	LOCAL PANGTI-1	G2 5	LOCAL WOKHA-1	G3 3	VRWB-93
G 2	LOCAL SUCHONOM A	G1 0	NUW B-3	G1 8	LOCAL DIMAPU R-1	G2 6	VRWB-59	G3 4	VRWB-100

G 3	NUWB-4	G1 1	VRW B-26	G1 9	VRWB-45	G2 7	LOCAL DIMAPUR -3	G3 5	VRWB- 104
G 4	LOCAL PEREN	G1 2	VRW B-27	G2 0	LOCAL PANGIT-2	G2 8	VRWB-75	G3 6	LOCAL MONSEN TI
G 5	LOCAL MEZDIPHE MA	G1 3	VRW B-68	G2 1	LOCAL DIMAPU R-2	G2 9	VRWB-77	G3 7	VRWB- 112
G 6	VRWB-17	G1 4	VRW B-32	G2 2	LOCAL AKUK	G3 0	VRBW-85	G3 8	VRWB- 115
G 7	VRWB-20	G1 5	VRW B-35	G2 3	VRWB-50	G3 1	VRWB-88	G3 9	VRWB- 116
G 8	VRWB-23	G1 6	VRW B-36	G2 4	VRWB-54	G3 2	LOCAL BAGHTY	G4 0	NUWB-2

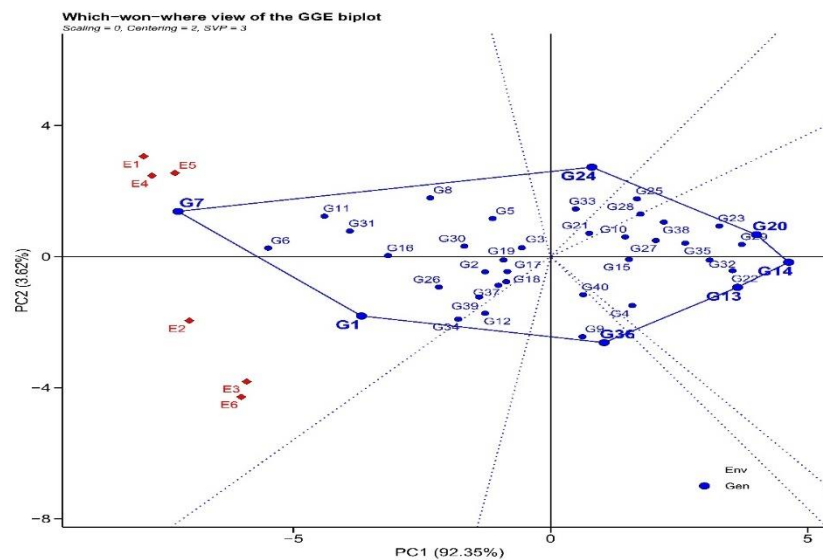


Fig. 4.25: GGE biplot polygon view depicting the “which-won-where” pattern showcases the combined impact of genotype main effects and $G \times E$ interaction for forty winged bean genotypes across four environments for Seed yield per plant

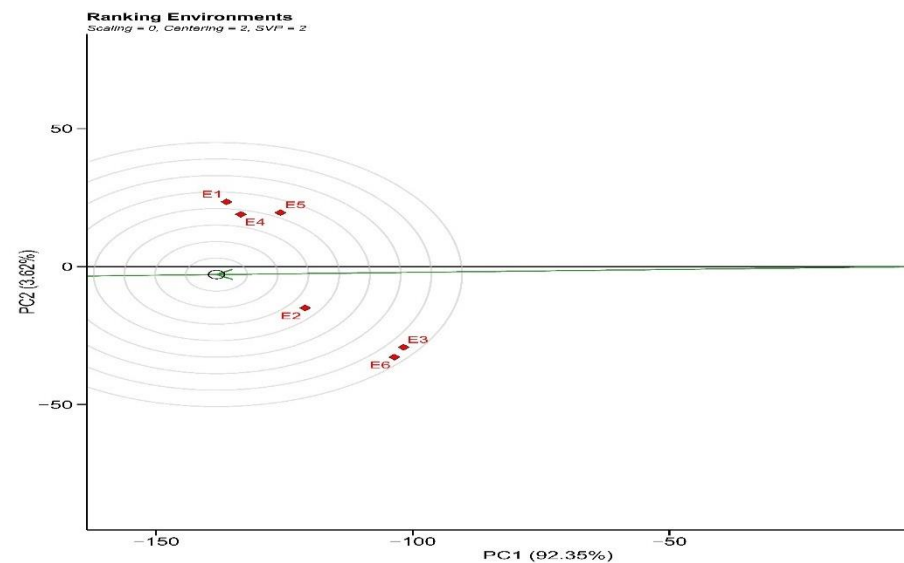


Fig. 4.26: GGE biplot “Env. Ranking” pattern compares environments, highlighting ideal environment with $G + G \times E$ interaction for forty winged bean genotypes across four environments for Seed yield per plant

G1	LOCAL WOKHA-2	G9	VRWB-24	G17	LOCAL PANGTI-1	G25	LOCAL WOKHA-1	G33	VRWB-93
G2	LOCAL SUCHONOMA	G10	NUWB-3	G18	LOCAL DIMAPUR-1	G26	VRWB-59	G34	VRWB-100
G3	NUWB-4	G11	VRWB-26	G19	VRWB-45	G27	LOCAL DIMAPUR-3	G35	VRWB-104
G4	LOCAL PEREN	G12	VRWB-27	G20	LOCAL PANGIT-2	G28	VRWB-75	G36	LOCAL MONSENTI
G5	LOCAL MEZDIPHEMA	G13	VRWB-68	G21	LOCAL DIMAPUR-2	G29	VRWB-77	G37	VRWB-112
G6	VRWB-17	G14	VRWB-32	G22	LOCAL AKUK	G30	VRWB-85	G38	VRWB-115
G7	VRWB-20	G15	VRWB-35	G23	VRWB-50	G31	VRWB-88	G39	VRWB-116
G8	VRWB-23	G16	VRWB-36	G24	VRWB-54	G32	LOCAL BAGHTY	G40	NUWB-2

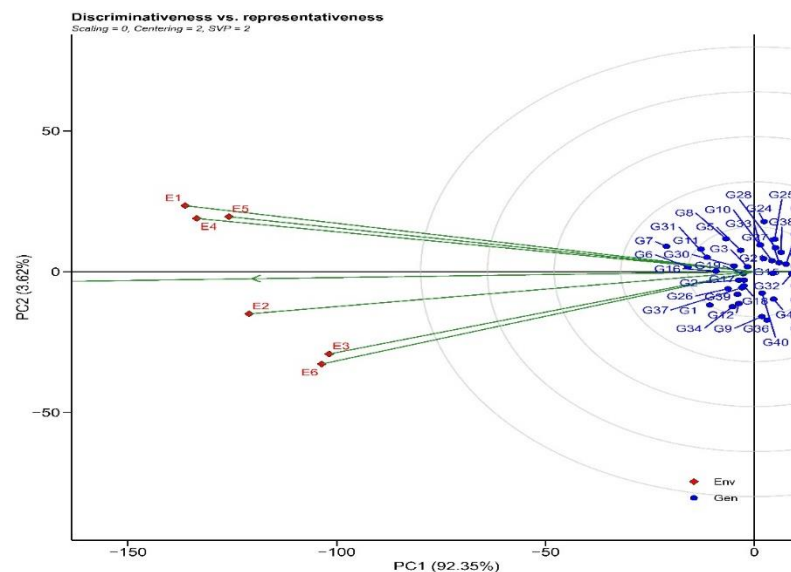


Fig. 4.27: GGE biplot “discriminativeness vs. representativeness” pattern compares genotypes, highlighting the ideal genotype with $G + G \times E$ interaction effect of forty bean genotypes across four environments for Seed yield per plant

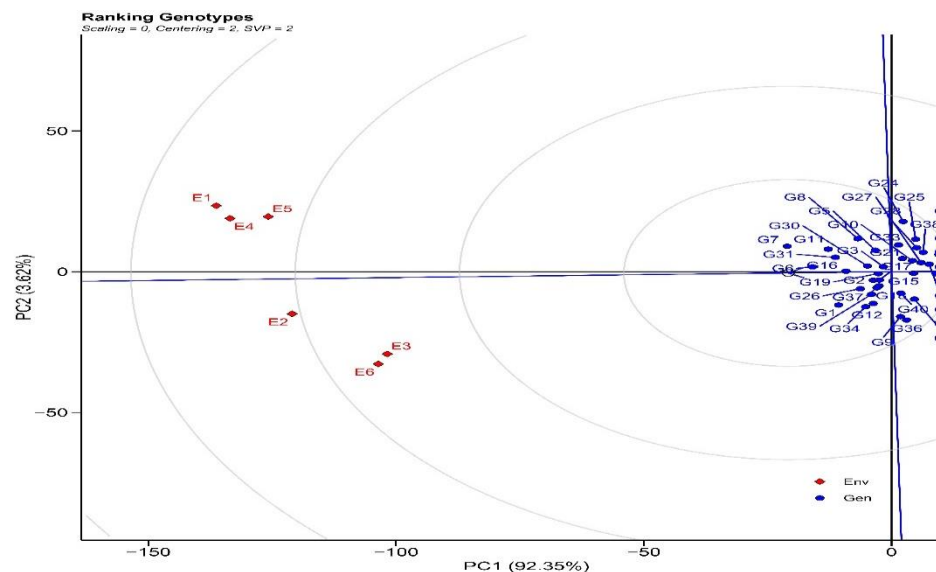


Fig. 4.28: The GGE biplot “genotypes ranking” pattern for genotype comparison with ideal genotype showing $G + G \times E$ interaction effect of forty winged bean genotypes across four environments for Seed yield per plant

G1	LOCAL WOKHA-2	G9	VRWB-24	G17	LOCAL PANGTI-1	G25	LOCAL WOKHA-1	G33	VRWB-93
G2	LOCAL SUCHONOMA	G10	NUWB-3	G18	LOCAL DIMAPUR-1	G26	VRWB-59	G34	VRWB-100
G3	NUWB-4	G11	VRWB-26	G19	VRWB-45	G27	LOCAL DIMAPUR-3	G35	VRWB-104
G4	LOCAL PEREN	G12	VRWB-27	G20	LOCAL PANGIT-2	G28	VRWB-75	G36	LOCAL MONSENTI
G5	LOCAL MEZDIPHEMA	G13	VRWB-68	G21	LOCAL DIMAPUR-2	G29	VRWB-77	G37	VRWB-112
G6	VRWB-17	G14	VRWB-32	G22	LOCAL AKUK	G30	VRBW-85	G38	VRWB-115
G7	VRWB-20	G15	VRWB-35	G23	VRWB-50	G31	VRWB-88	G39	VRWB-116
G8	VRWB-23	G16	VRWB-36	G24	VRWB-54	G32	LOCAL BAGHTY	G40	NUWB-2

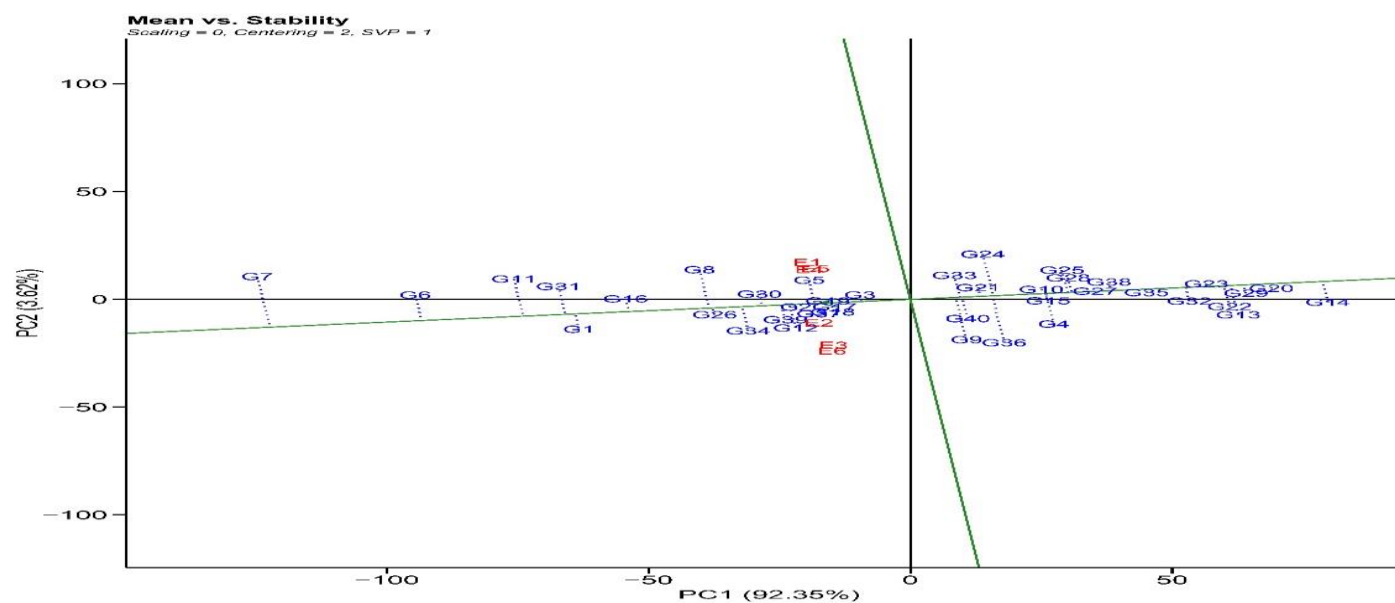


Fig. 4.29: The GGE biplots depiction of the “mean vs. stability” pattern of forty-winged bean genotypes across four environments for **Seed yield per plant**

G1	LOCAL WOKHA-2	G9	VRWB-24	G17	LOCAL PANGTI-1	G25	LOCAL WOKHA-1	G33	VRWB-93
G2	LOCAL SUCHONOMA	G10	NUWB-3	G18	LOCAL DIMAPUR-1	G26	VRWB-59	G34	VRWB-100
G3	NUWB-4	G11	VRWB-26	G19	VRWB-45	G27	LOCAL DIMAPUR-3	G35	VRWB-104
G4	LOCAL PEREN	G12	VRWB-27	G20	LOCAL PANGIT-2	G28	VRWB-75	G36	LOCAL MONSENTI
G5	LOCAL MEZDIPHEMA	G13	VRWB-68	G21	LOCAL DIMAPUR-2	G29	VRWB-77	G37	VRWB-112
G6	VRWB-17	G14	VRWB-32	G22	LOCAL AKUK	G30	VRWB-85	G38	VRWB-115
G7	VRWB-20	G15	VRWB-35	G23	VRWB-50	G31	VRWB-88	G39	VRWB-116
G8	VRWB-23	G16	VRWB-36	G24	VRWB-54	G32	LOCAL BAGHTY	G40	NUWB-2

4.9.1.5. Assessment of genotypes dependent on the perfect genotype

A perfect genotype is defined as one that is clearly constant in performance and likely has the best Seed yield per plant across the test environments. The ideal genotypes are those that are closest to the perfect genotype, which is located in the primary concentric circle of the GGE biplot graph (Fig. 4.28). Because of this, genotype G6 which was positioned near the primary concentric circle, was the one that was nearest from the ideal genotype location (Fig. 4.28). VRWB-36 (G16), VRWB-45 (G19) and VRWB-88 (G31), which were near VRWB-17 (G6), were the more attractive genotypes than other winged bean genotypes. Despite this, the genotypes Local pangti-2 (G20), and VRWB-32 (G14) were adapted for specific environments and considered more undesirable than other chickpea genotype's grain yield. Near the biplot origin, four genotypes VRWB-45 (G19), Local Dimapur-1 (G18), Local Pangti-1 (G17) and NUWB-4 (G3) were less sensitive to the environmental change.

4.9.1.6. Mean performance vs. Stability of the Genotypes

The GGE Biplot investigation of the forty genotypes in four conditions is shown in (Fig. 4.29). An Average Environment Coordination (AEC) approach was used to determine the mean Seed yield per plant performance and genotype stability. Accordingly, based on the situations, VRWB-20(G7), VRWB-17(G6), VRWB-26 (G11), VRWB-88 (G31), and Local Wokha-2 (G1) were the genotypes with the highest PC1 values, while VRWB-32 (G14), had the lowest mean seed yield per plant. Mean grain yields of the genotypes were in the accompanying request: VRWB-20 (G7)> VRWB-17 (G6)>(G11)> VRWB-88 (G31)>Local-wokha-2(G1)> VRWB-17 (G16) >VRWB-23 (G8)> VRWB-59 (G26)>G34>(G30)>(G39)>(G12)>LocalSuchonoma(G2)>LocalMedziphema(G5)>VRWB-112(G37)>VRWB-45 (G19)>VRWB-36(G18)>Local pangti-1(G17)>NUWB-3 (G3). When making the decision regarding across the environments, stability and higher Seed yield per plant should be taken into consideration simultaneously. The genotypes that were closest to the point in

terms of PC2 were VRWB-59 (G26), Local Suchonoma (G2) and Local Pangti-1 (G17). These genotypes were steadily improving with higher Seed yield per plant than anticipated. The most factor genotype is identified as VRWB-20 (G7). Thus, NUWB-1 (G3) and VRWB-45 (G19), showed increasing stability that corresponded to seed yield per plant.

4.10. Biochemical analysis

4.10.1. Protein percent of green pod

The protein percent of green pods ranged from 28.17 % to 20.15% with average mean of 24.29% (Table. 4.31). The maximum protein percent was recorded in VRWB-23 (28.17%) followed by VRWB-75 (27.81%) and Local pangti-2 (27.08%) minimum protein was recorded in Local suchonoma (19.86%). followed by Local Dimapur-3 (20.15%) 15 genotypes were found superior over the best check Local Medziphema (23.47%) for this character.

4.10.2. Protein percent of winged bean seed

The protein percent of seed ranged from 30.55 % to 49.07% with average mean of 41.84% (Table.4.31.). The maximum protein percent was recorded in VRWB-23 (32.56%) followed Local pangti-2 and Local pangti-1 (48.75%) and NUWB-4 (46.80%) minimum protein was recorded in Local dimapur-3 (30.55%) followed by Local suchonoma (35.75%), VRWB-93 (35.75%) and VRWB-116 (35.75%). 15 genotypes were found superior over the best check Local Medziphema (42.25%) for this character.

4.10.3. Oil percent of winged bean seed:

The oil percent of green pods ranged from 14.80 % to 6.13% with average mean of 9.89% (Table.4.31.). The maximum oil percent was recorded in VRWB-116 (14.80%) followed by VRWB-85 (14.30%), Local Mongsenyimti (14.30%), Local suchonoma (13.60%) and Local wokha-1(13.34%) minimum oil was recorded in Local Pangti-1 (6.13%) followed by VRWB-59 (6.28%), VRWB-26 (6.32%), Local akuk (6.65%) and NUWB (6.40). Three genotypes

were found superior over the best check Local suchonoma (13.60%) for this character.

Table 4.31: Analysis of Crude protein content in green pods, seeds and oil content in winged bean genotypes

Sl. No.	Genotypes	Crude protein content in seeds	Crude protein content in green Pods	Oil content
1	LOCAL WOKHA-2	42.25 ^{defghijk}	23.47 ^{abcdef}	13.00 ^{klm}
2	LOCAL SUCHONOMA	35.75 ^{abc}	19.86 ^a	8.80 ^{cde}
3	NUWB-4	46.80 ^{ijklm}	26.00 ^{efghi}	9.21 ^{def}
4	LOCAL PEREN	42.25 ^{defghijk}	23.47 ^{abcdef}	9.60 ^{defg}
5	LOCAL MEZDIPHEMA	42.25 ^{defghijk}	23.47 ^{abcdef}	13.60 ^{lmn}
6	VRWB-17	40.30 ^{bcdefghi}	22.39 ^{abcd}	10.25 ^{fgh}
7	VRWB-20	39.00 ^{bcdefg}	33.80 ^l	7.10 ^{ab}
8	VRWB-23	49.07 ^m	28.17 ^{ijk}	12.60 ^{kl}
9	VRWB-24	40.95 ^{cdefghij}	26.65 ^{fghi}	9.00 ^{def}
10	NUWB-3	46.15 ^{ijklm}	27.30 ^{ghi}	6.40 ^a
11	VRWB-26	42.90 ^{defghijkl}	24.05 ^{bcdefg}	6.32 ^a
12	VRWB-27	45.50 ^{hijklm}	25.28 ^{defghi}	7.33 ^{ab}
13	NUWB-1	42.25 ^{defghijk}	23.47 ^{abcdef}	8.68 ^{cde}
14	VRWB-32	45.50 ^{hijklm}	21.32 ^{abc}	6.48 ^a
15	VRWB-35	41.60 ^{cdefghijk}	23.11 ^{abcdef}	10.30 ^{fgh}
16	VRWB-36	39.65 ^{bcdefgh}	22.03 ^{abcd}	12.03 ^{ijk}
17	LOCAL PANGTI-1	48.75 ^{lm}	27.08 ^{ghi}	6.13 ^a
18	LOCAL DIMAPUR-1	37.05 ^{bcd}	20.58 ^{ab}	8.20 ^{bcd}
19	VRWB-45	44.20 ^{fghijkl}	24.56 ^{cdefgh}	7.50 ^{ab}
20	LOCAL PANGIT-2	48.75 ^{lm}	27.08 ^{ghi}	9.10 ^{def}
21	LOCAL DIMAPUR-2	42.25 ^{defghijk}	23.47 ^{abcdef}	10.40 ^{fgh}
22	LOCAL AKUK	43.55 ^{efghijkl}	24.19 ^{cdefg}	6.65 ^a
23	VRWB-50	46.80 ^{ijklm}	26.00 ^{efghi}	7.01 ^{ab}
24	VRWB-54	42.25 ^{defghijk}	23.47 ^{abcdef}	12.30 ^{jkl}
25	LOCAL WOKHA-1	44.85 ^{ghijklm}	24.92 ^{cdefghi}	13.34 ^{klm}
26	VRWB-59	40.30 ^{bcdefghi}	30.55 ^{jk}	6.28 ^a
27	LOCAL DIMAPUR-3	30.55 ^a	20.15 ^a	9.30 ^{def}
28	VRWB-75	47.49 ^{klm}	27.81 ^{hij}	13.00 ^{klm}
29	VRWB-77	34.45 ^{ab}	21.45 ^{abc}	12.50 ^{jkl}
30	VRBW-85	37.70 ^{bcde}	31.20 ^{kl}	14.30 ^{mn}
31	VRWB-88	38.35 ^{bcdef}	21.31 ^{abc}	8.80 ^{cde}
32	LOCAL BAGHTY	40.95 ^{cdefghij}	23.40 ^{abcdef}	12.60 ^{kl}
33	VRWB-93	35.75 ^{abc}	19.86 ^a	7.30 ^{ab}
34	VRWB-100	39.65 ^{bcdefgh}	22.03 ^{abcd}	10.75 ^{ghi}
35	VRWB-104	46.80 ^{ijklm}	26.00 ^{efghi}	9.70 ^{efg}
36	LOCAL MONSENTI	42.25 ^{defghijk}	23.47 ^{abcdef}	14.30 ^{mn}
37	VRWB-112	41.60 ^{cdefghijk}	23.11 ^{abcdef}	11.20 ^{hij}
38	VRWB-115	40.95 ^{cdefghij}	22.75 ^{abcde}	10.01 ^{efgh}
39	VRWB-116	35.75 ^{abc}	21.45 ^{abc}	14.80 ⁿ
40	NUWB-2	39.00 ^{bcdefg}	21.67 ^{abc}	9.60 ^{defg}
	GM	41.84	24.29	9.89
	Range-(Max)	49.07	28.17	14.80
	Range-(Min)	30.55	20.15	6.13
	CV	7.29	7.44	7.64
	SEM	1.76	1.04	0.44
	CD 5%	4.96	2.94	1.23
	CD 1%	6.58	3.90	1.63

4.11. Chlorophyll content in winged bean leaves

For the Total chlorophyll of winged bean genotypes (Table 4.32) ranged from 2.872 A to 0.391A with average mean of 1,561 A. The maximum Total chlorophyll percent was recorded in VRWB-27 (2.871A) followed VRWB-24 (2.749A) and VRWB-100 (2.748A), VRWB-104 (2.751A) and VRWB-116 (2.411A) minimum was recorded in Local baghty (0.391A) followed by VRWB-20 (0.416 A), Local Mongsenyimti (0.574A) and Local Pangti-2 (0.518A) six genotypes were found superior over the best check Local Medziphema (2.396A) for this character.

For the chlorophyll-A, winged bean genotypes ranged (Table 4.32) from 0.917 A to 0.441A with average mean of 0.678 A. The maximum chlorophyll-A was recorded in local Medziphema (0.917A) followed by VRWB-27 (0.900A), VRWB-23 (0.888A), VRWB-24(0.863A) and VRWB-100 (0.877A), VRWB-104 (0.878A) and VRWB-116 (0.855A) minimum chlorophyll-A was recorded in VRWB-20 (0.441 A) followed by Local baghty (0.458A), Local Pangti-2 (0.485A) and Local Mongsenyimti (0.511A), None of the genotypes were found superior over the best check Local Medziphema (0.917A) for this character.

For the chlorophyll-B of winged bean genotypes ranged (Table 4.32) from 1.788 A to 0.176 A with average mean of 0.883 A. The maximum chlorophyll-B was recorded in VRWB-27 (1.788 A) followed by local Medziphema (1.283 A), VRWB-23 (1.580 A), VRWB-24 (1.693A) and VRWB-100 (1.706A), VRWB-104 (1.692 A) and VRWB-116 (1.404A) minimum chlorophyll-B was recorded in Local baghty (0.176 A), VRWB-20 (0.237A), Local Suchonoma (0.249 A) followed by VRWB-32 (0.279 A), Local wokha-2 (0.349A) and Local Mongsenyimti (0.255 A), None of the genotypes were found superior over the best check Local Medziphema (0.917A) for this character.

Table 4.32: Total Chlorophyll, Chlorophyll-A and Chlorophyll-B studied in 40 genotypes of winged bean

S. No.	Genotypes	Total Chlorophyll	Chlorophyll-A	Chlorophyll-B
1	LOCAL WOKHA-2	1.794 ^p	0.699 ^{abcdeh}	1.074 ^{ghi}
2	LOCAL SUCHONOMA	0.653 ^d	0.549 ^{abc}	0.249 ^a
3	NUWB-4	1.778 ^p	0.713 ^{abcdeh}	1.041 ^{ghi}
4	LOCAL PEREN	2.184 ^s	0.794 ^{bcdeh}	1.354 ^{ik}
5	LOCAL MEZDIPHEMA	2.396 ^v	0.917 ^{fghijk}	1.283 ^{ij}
6	VRWB-17	2.052 ^r	0.745 ^{abcdeh}	1.300 ^{ij}
7	VRWB-20	0.416 ^a	0.441 ^a	0.237 ^a
8	VRWB-23	2.625 ^w	0.888 ^{efghij}	1.580 ^{klm}
9	VRWB-24	2.749 ^x	0.863 ^{defghij}	1.693 ^{mn}
10	NUWB-3	1.233 ⁱ	0.648 ^{abcdeh}	0.652 ^{De}
11	VRWB-26	2.286 ^{tu}	0.814 ^{cdeh}	1.399 ^{ijkl}
12	VRWB-27	2.871 ^y	0.900 ^{efghij}	1.788 ^{mn}
13	NUWB-1	2.297 ^u	0.809 ^{cdeh}	1.371 ^{jk}
14	VRWB-32	0.641 ^d	0.531 ^{abc}	0.279 ^{ab}
15	VRWB-35	0.800 ^f	0.543 ^{abc}	0.413 ^{abcd}
16	VRWB-36	1.405 ^l	0.672 ^{abcdeh}	0.735 ^{ef}
17	LOCAL PANGTI-1	1.394 ^{kl}	0.742 ^{abcdeh}	0.610 ^{Cde}
18	LOCAL DIMAPUR-1	1.352 ^{jk}	0.663 ^{abcdeh}	0.744 ^{ef}
19	VRWB-45	1.336 ^j	0.613 ^{abcdeh}	0.805 ^{efg}
20	LOCAL PANGIT-2	0.518 ^b	0.485 ^{ab}	0.246 ^a
21	LOCAL DIMAPUR-2	1.198	0.679 ^{abcdeh}	0.555 ^{bcde}
22	LOCAL AKUK	0.853 ^g	0.595 ^{abcde}	0.359 ^{abc}
23	VRWB-50	0.429 ^a	0.476 ^a	0.177 ^a
24	VRWB-54	1.614 ⁿ	0.669 ^{abcdeh}	0.979 ^{fgh}
25	LOCAL WOKHA-1	0.672 ^d	0.513 ^{abc}	0.349 ^{abc}
26	VRWB-59	1.722 ^o	0.683 ^{abcdeh}	1.030 ^{ghi}
27	LOCAL DIMAPUR-3	1.561 ^m	0.734 ^{abcdeh}	0.810 ^{efg}
28	VRWB-75	1.340 ^j	0.693 ^{abcdeh}	0.666 ^{De}
29	VRWB-77	1.898 ^q	0.748 ^{abcdeh}	1.125 ^{hij}
30	VRBW-85	0.738 ^e	0.566 ^{abcd}	0.310 ^{ab}
31	VRWB-88	0.865 ^g	0.566 ^{abcd}	0.446 ^{De}
32	LOCAL BAGHTY	0.391 ^a	0.458 ^a	0.176 ^{ab}
33	VRWB-93	1.133 ^h	0.636 ^{abcdeh}	0.552 ^{efg}
34	VRWB-100	2.748 ^x	0.877 ^k	1.706 ^o
35	VRWB-104	2.751 ^x	0.878 ^k	1.692 ^o
36	LOCAL MONGSENYIMTI	0.574 ^c	0.511 ^a	0.255 ^{abcd}
37	VRWB-112	2.308 ^u	0.777 ^{jk}	1.477 ⁿ
38	VRWB-115	2.081 ^r	0.824 ^{ghijk}	1.174 ^{lmn}
39	VRWB-116	2.411 ^v	0.855 ^{ijk}	1.404 ⁿ
40	NUWB-2	2.245 ^t	0.837 ^{hijk}	1.307 ^{mn}
RANGE	(MAX)	2.871	0.91	1.788
	(MIN)	0.391	0.441	0.176
GM		1.561	0.678	0.883
CV		2.331	7.980	2.351
SEM		0.021	0.031	0.012
CD 5%		0.059	0.088	0.034
CD 1%		1.561	0.678	0.883

4.12. Morphology of Winged Bean

The stem and winged pod color of all 40 genotypes were found to be green. The surface texture of the pods was generally medium for most genotypes, except for Local Akuk and VRWB-50, which exhibited a rough texture. In contrast, genotypes such as VRWB-24, VRWB-26, VRWB-32, Local Pangti-2, Local Dimapur-2, VRWB-77, VRWB-93, VRWB-100, VRWB-104, VRWB-112, and Local Mongsenyimti displayed smooth pod texture.

Regarding pod shape, the suture of winged beans was predominantly rectangular in most genotypes, as reported by Yulianah *et al.*, (2020) and Yadav (2021), with exceptions including NUWB-3, VRWB-27, Local Pangti-1, Local Pangti-2, Local Wokha-1, VRWB-59, Local Dimapur-3, Local Baghty, VRWB-93, VRWB-100, and VRWB-104, which exhibited a flat-suture structure. Additionally, all 40 genotypes showed the presence of specks on the pods.

Among the various plant parts, different leaflet shapes were observed across the genotypes. The ovate shape was dominant in 18 genotypes, followed by the deltoid shape in 15 genotypes, and the lanceolate shape was found in 7 genotypes. All pods were green in color, except for VRWB-93, which was predominantly green at early stages, turning purple at the edges upon maturity. The calyx color was green for all 40 genotypes, while the corolla was mostly purplish-blue. These findings were consistent with those of Yadav (2021), except for VRWB-85, which exhibited a white corolla in the E4 environment (summer 2023), and Local Baghty, VRWB-104, and Local Mongsenyimti, which showed purple corollas.

The seed color varied among the genotypes, with brown being the most common, except for VRWB-20 and VRWB-54, which had cream-colored seeds. Local Suchonoma, VRWB-23, and VRWB-77 displayed brown-black seeds, while VRWB-88 and VRWB-35 showed purplish-black seeds. These results

align with those reported by Yulianah *et al.*, (2020), Ishthifaiyyah *et al.*, (2021), Yadav (2021), and Sriwichai *et al.*, (2022).

4.13. Analysis of Variance for Timely, Late, and Very Late Sown Conditions

The analysis of variance for the evaluated traits revealed highly significant differences among the winged bean genotypes across timely, late, and very late sown conditions (Table 4.1). This significant variation indicates the presence of substantial genetic variability among the genotypes. Genetic variation within a population is crucial for the effective selection and management of yield improvement programs.

Similar findings have been reported by Iwo *et al.*, (2006), Yadav (2018), Dodake *et al.*, (2019), Sarode and Dodake (2019), Desai *et al.*, (2020), Dutta *et al.*, (2021), Adegboyega *et al.*, (2021), and Kader *et al.*, (2022).

4.14 Genetic Variability Under Timely, Late, and Very Late Sown Conditions

A wide range of genetic variability was observed for pod yield per plant, seed yield per plant, tuber weight, and pod width under timely, late, and very late sown conditions (Table 4.3). Traits such as pod width, 100-seed weight, plant height, dry pod weight, tuber width, and the number of seeds per pod exhibited genetic variability across all three sowing conditions.

The population mean for several traits declined under late and very late sown conditions compared to timely sown conditions. Specifically, pod yield per plant decreased by 16.19% and 20.35%, 100-seed weight by 0.67% and 2.20%, the number of seeds per pod by 8.90% and 36.15%, and seed yield per plant by 16.07% and 29.81%. These findings align with previous research by Yadav, (2018), Dodake *et al.*, (2018), Sarode and Dodake, (2019), Desai *et al.*, (2020), Dutta *et al.*, (2021), and Adegboyega *et al.*, (2021).

4.15. Genotypic and Phenotypic Coefficient of Variation

The coefficient of variation (Table 4.3) provides insights into the degree of variation present in a population. A higher phenotypic coefficient of variation (PCV) compared to the genotypic coefficient of variation (GCV) indicates that a trait is more sensitive to environmental modifications, limiting its potential for improvement through selection (Abate *et al.*, 2015). Conversely, when the difference between PCV and GCV is small, it suggests that environmental influence is minimal, and the variability in these traits is primarily controlled by genetic factors (Singh *et al.*, 2018).

Traits such as tuber weight, tuber length, tuber diameter, pod yield per plant, days to first flowering, and seed yield per plant exhibited the highest GCV and PCV estimates across all three experimental conditions. This indicates a high potential for genetic improvement through selection. These findings are consistent with previous studies conducted by Singh *et al.*, (2016), Yadav (2018), Dodake *et al.*, (2018), Desai *et al.*, (2020), Dutta *et al.*, (2021), and Adegboyega *et al.*, (2021), which reported similar genetic variation for number of branches per plant, number of pods per plant, and seed yield per plant. Additionally, Kant and Nandan (2018) found significant genetic variability in number of branches per plant, seed yield per plant, stover yield per plant, and number of pods per plant. Similar findings were also reported by Singh *et al.*, (2018) for number of primary branches per plant, seed yield per plant, number of seeds per pod, and number of pods per plant; Patidar *et al.*, (2018) for seed yield; Padmaja *et al.*, (2020, 2017) and Gupta *et al.*, (2021) for seed yield per plant and number of branches per plant; Mohanty *et al.*, (2020) for biological yield; and Sasipriya *et al.*, (2022) for 1000-seed weight.

In contrast, traits such as days to maturity, pod length, number of seeds per pod, and pod width exhibited low PCV and GCV estimates, suggesting a limited scope for genetic improvement through selection. Similar findings have

been reported by Dutta *et al.*, (2021) and Singh *et al.*, (2018) for pod length, as well as by Sriwichai *et al.*, (2021), Thakur *et al.*, (2022), Shekhawat *et al.*, (2013), Jadhav *et al.*, (2013), Vanishree *et al.*, (2013a), and Hika *et al.*, (2015) for days to maturity.

4.15. Genotypic and Phenotypic Coefficient of Variation

The coefficient of variation (Table 4.3) provides insight into the extent of variability present in a population. A higher phenotypic coefficient of variation (PCV) compared to the genotypic coefficient of variation (GCV) for a given trait shows that the trait is highly affected by environmental factors, reducing the potential for genetic improvement through selection (Abate *et al.*, 2015). Conversely, a smaller difference between PCV and GCV suggests that environmental influence is minimal, and genetic factors predominantly control the observed variability (Singh *et al.*, 2018).

The traits tuber weight, tuber length, tuber diameter, pod yield per plant, days to first flowering, and seed yield per plant exhibited the highest estimates of both GCV and PCV across all three growing conditions. This indicates a strong genetic basis for these traits and suggests good potential for improvement through selection. These findings are consistent with earlier studies, including those by Singh *et al.*, (2016), Yadav (2018), Dodake *et al.*, (2018), Desai *et al.*, (2020), Dutta *et al.*, (2021), and Adegboyega *et al.*, (2021), which reported high variability for number of branches per plant, number of pods per plant, and seed yield per plant. Similarly, Kant and Nandan (2018) found high variation for number of branches per plant, seed yield per plant, stover yield per plant, and number of pods per plant, while Singh *et al.*, (2018) reported similar findings for number of primary branches per plant, seed yield per plant, number of seeds per pod, and number of pods per plant. Additionally, Patidar *et al.*, (2018) observed high variation in seed yield, and research by Padmaja *et al.*, (2017, 2020) and Gupta *et al.*, (2021) confirmed high variability for seed yield per plant and number of branches per plant. Other studies, such as Mohanty *et al.*, (2020) and

Sasipriya *et al.*, (2022), reported high variability for biological yield and 1000-seed weight, respectively.

In contrast, traits such as days to maturity, pod length, number of seeds per pod, and pod width exhibited low PCV and GCV estimates, indicating limited potential for genetic improvement through selection. These findings align with previous studies by Dutta *et al.*, (2021) and Singh *et al.*, (2018) for *pod length*, as well as Sriwichai *et al.*, (2021), Thakur *et al.*, (2022), Shekhawat *et al.*, (2013), Jadhav *et al.*, (2013), Vanishree *et al.*, (2013a), and Hika *et al.*, (2015), who reported similar results for *days to maturity*

4.15.1. Heritability (Broad Sense) and Genetic Advance as a Percentage of the Mean

The genotypic coefficient of variation (GCV) alone does not provide a complete indication of the heritable portion of total variation. However, heritability estimates are more reliable indicators of the extent to which a trait is genetically inherited. Broad-sense heritability accounts for the contribution of additive genetic effects, dominance interactions, and epistatic (non-allelic) interactions, offering insights into the degree of genetic control over a trait.

High broad-sense heritability (above 60%) was recorded for several traits, including tuber weight, 100-seed weight, days to flowering (first and 50%), pod initiation, maturity, pod width, dry pod weight, tuber length, and seed yield per plant across diverse environments (Table 4.3). This high heritability suggests that these traits are strongly governed by genetic factors, remaining relatively stable across different environmental conditions. Consequently, breeders can make accurate predictions about a trait's potential for improvement through selection. These findings align with previous research by Kant and Nandan, (2018), Yadav (2018), Dodake *et al.*, (2018), Gogoi, (2019), Desai *et al.*, (2020), and others, further reinforcing the significance of these traits in crop improvement programs. Because these traits exhibit high heritability, they are

less influenced by environmental variability. As a result, selecting for these characteristics is likely to yield consistent improvements in productivity, providing a strong foundation for stable and reliable crop enhancement. This has practical implications for agricultural breeding, as breeders can confidently enhance seed weight, flowering time, and pod width to improve the overall efficiency and productivity of winged bean cultivars.

The genetic advance as a percentage of the mean (Table 4.3) offers valuable insight into the potential improvements achievable through selection. High genetic advance values indicate that a trait is primarily controlled by additive genetic factors, making it highly responsive to selection. Traits exhibiting high genetic advance included plant height, tuber weight, flowering initiation, pod initiation, maturity, dry pod weight, seed yield per plant, and tuber diameter. These characteristics demonstrated strong additive gene action, making them ideal candidates for selective breeding programs. Previous studies by Nandan *et al.*, (2010), Singh *et al.*, (2016), and others support these findings, emphasizing the effectiveness of phenotypic selection for these traits.

A high genetic advance suggests that a trait can show substantial improvement within just a few generations of selection. Consequently, focusing on these characteristics can lead to rapid and significant enhancements in yield, resilience, and overall plant performance. This strategy is particularly beneficial for staple crops like winged bean, where maximizing productivity through genetic improvement plays a crucial role in meeting food and nutritional demands. Furthermore, traits with strong additive gene influence offer a sustainable breeding approach, ensuring that desirable characteristics are maintained across successive generations, leading to long-term stability and productivity gains.

Several key traits, including tuber weight, tuber diameter, stem height, pod length, pod width, and seed yield per plant, exhibited both a high heritability

and high genetic advance. This combination suggests that these traits are primarily governed by additive genetic factors, making them excellent targets for phenotypic selection. The presence of a high heritability alongside high genetic advance provides a clear path for breeders to improve these traits effectively and consistently. Additionally, traits with strong genetic control are less susceptible to environmental variability, ensuring that improvements are stable across different growing conditions. Studies by Singh *et al.*, (2016), Gupta *et al.*, (2021), Jamir *et al.*, (2020), and others validate this approach, emphasizing the reliability of selecting for traits with this genetic profile.

The stability and robustness observed in winged bean's genetic traits suggest that meaningful genetic improvements can be achieved without significant concerns about trait instability or inconsistent response to selection. These findings reinforce the potential of winged bean as a viable target for breeding programs focused on sustainable productivity improvements. By leveraging this genetic resilience, breeders can develop new cultivars that retain desirable traits across diverse environments, ensuring a reliable and adaptable food source for future agricultural needs.

4.15.2. Heritability (Broad Sense) and Genetic Advance as a Percentage of the Mean

The genotypic coefficient of variation alone does not provide a complete measure of total heritable variation. However, heritability estimates serve as better indicators of the proportion of variation that is genetically inherited. Broad-sense heritability accounts for the combined effects of additive genetic variance, dominance interactions (allelic), and epistatic interactions (non-allelic).

High broad-sense heritability (>60%) was observed for several traits, including tuber weight, 100-seed weight, days to first and 50% flowering, days to pod initiation and maturity, pod width, dry pod weight, tuber length, and seed

yield per plant across diverse environments (Table 4.3). High heritability suggests that these traits are primarily controlled by genetic factors and remain stable across different environmental conditions. This stability enables breeders to make accurate predictions regarding trait performance and potential genetic gains through selection. The findings align with previous studies by Kant and Nandan, (2018), Yadav, (2018), Dodake *et al.*, (2018), Gogoi, (2019), Desai *et al.*, (2020), and others, further reinforcing the importance of these traits in breeding programs.

The strong genetic basis for high heritability in these traits means they are less influenced by environmental fluctuations. Consequently, selective breeding for these characteristics is likely to yield consistent results across different growing conditions, providing a foundation for stable and reliable crop improvement. This has direct applications in agricultural breeding, where enhancing traits such as seed weight, flowering time, and pod width can significantly improve the productivity and efficiency of winged bean cultivars.

Genetic advance as a percentage of the mean (Table 4.3) provides insight into the potential genetic improvement achievable through selection. High genetic advance values indicate that a trait is likely governed by additive genetic effects, making it highly responsive to selection. Traits that exhibited high genetic advance included plant height, tuber weight, flowering initiation, pod initiation, maturity, dry pod weight, seed yield per plant, and tuber diameter. Strong additive gene action observed in these traits makes them particularly suitable for phenotypic selection. Previous research by Nandan *et al.*, (2010), Singh *et al.*, (2016), and others supports these findings, highlighting the responsiveness of such traits to selection.

A high genetic advance value suggests that a trait can show substantial improvement within a few generations of selection. The presence of strong additive genetic influence makes these traits ideal targets for breeding programs

aiming to enhance yield, resilience, and overall plant performance. This approach is particularly beneficial for staple crops like winged bean, where increasing productivity through selection can contribute to food security and nutritional sustainability. Moreover, traits governed by additive genetic factors ensure that desirable characteristics are consistently maintained and reinforced across successive generations, offering a sustainable pathway for long-term crop improvement.

Some traits, including tuber weight, tuber diameter, plant height, pod length, pod width, and seed yield per plant, exhibited both high heritability and high genetic advance. This combination suggests that these traits predominantly controlled through additive genetic factors and are excellent candidates for phenotypic selection. The presence of high heritability alongside strong genetic advance allows breeders to improve these traits effectively while minimizing the impact of environmental variability. Studies by Singh *et al.*, (2016), Gupta *et al.*, (2021), Jamir *et al.*, (2020), and others support the effectiveness of selecting for traits with this combination, emphasizing their importance in breeding programs.

The genetic robustness observed in winged bean traits suggests that breeding efforts can lead to meaningful improvements without concerns about trait instability or weak selection response. This strengthens the case for winged bean as a crop well-suited for breeding programs aimed at achieving sustainable productivity gains, even under varying environmental conditions. By leveraging the resilience of these genetic traits, breeders can develop new cultivars with enhanced adaptability, ensuring a reliable and productive food source across diverse agricultural environments

4.16. Correlation Coefficient

Seed yield per plant is a complex trait influenced by multiple interdependent quantitative characters, many of which are less affected by

environmental fluctuations. Understanding the interrelationships among these traits is valuable for plant breeders, as it can help identify measurable traits that contribute to yield.

Direct selection for seed yield alone may not be effective due to its high sensitivity to environmental variation. Therefore, selecting yield-related components that have a strong influence on seed yield but are less affected by environmental factors may be a more reliable approach. When selection is applied to improve a trait closely associated with seed yield, it can simultaneously impact other correlated traits.

Thus, understanding the relationships between different traits and their association with seed yield per plant provides essential guidance for plant breeders. This knowledge helps in selecting traits that can be used as indirect selection criteria for improving seed yield through closely correlated characters.

4.17.1 Correlation Between Yield and Its Components

In the present study, genotypic and phenotypic correlations among sixteen quantitative traits of winged bean were analyzed (Table 4.4). The magnitude of the genotypic correlation coefficient was higher than the corresponding phenotypic correlation for most traits, indicating that environmental factors played a minimal role in their expression. This suggests a strong inherent genetic association among these traits (Singh *et al.*, 2019).

A highly significant and positive correlation was recorded between seed yield per plant and several traits, including plant height (m), pod yield per plant, number of pods per plant, number of seeds per pod, and 100-seed weight under all three planting conditions. Seed yield per plant also showed a significant and positive correlation with the number of seeds per pod in all conditions, aligning with findings by Nandan *et al.*, (2009) and Mohamadali and Madalageri, (2012).

Similarly, a significant association between seed yield and the number of pods per plant was reported by Nandan *et al.*, (2009), Yadav (2018), and Yadav (2021). The positive correlation between seed yield per plant and 100-seed weight is consistent with studies by Vijay *et al.*, (1980), Nandan *et al.*, (2009), and Shivade *et al.*, (2011). Additionally, seed yield exhibited a positive and significant correlation with pod length under very late planting conditions, as previously reported by Prasanth *et al.*, (2015), Yadav, (2018), and Yadav, (2021).

Based on these correlation studies, selection criteria focused on number of pods per plant, number of seeds per pod, 100-seed weight, and pod length could enhance yield improvement in winged bean. Furthermore, additional traits such as dry pod weight (g), tuber weight (g), tuber diameter (cm), tuber length (cm), and days to maturity may also be considered to achieve better results in yield improvement.

4.17. Path coefficient analysis

Seed yield per plant is one of the complex quantitative trait influenced by multiple independent characters, each contributing directly and indirectly through other traits. Since correlation values only measure interrelationships without specifying the direction and extent of direct and indirect effects of different component traits on seed yield per plant, it is essential to analyse these effects in detail. Understanding the relationship between seed yield and other quantitative traits helps assess their impact and determine their contributions to overall yield.

Correlation studies, when combined with path coefficient analysis, provide a clearer picture of the cause-and-effect relationships among different traits. According to Wright, (1921), path analysis is a standardized partial regression technique that partitions correlation coefficients into direct and

indirect effects, helping to clarify causal relationships among interrelated variables.

The results (Table 4.6) indicate that days to first flowering, pod yield per plant (g), number of pods per plant, number of seeds per pod, and 100-seed weight had a high and positive direct effect on seed yield per plant under all three conditions—timely, late, and very late planting. These findings are consistent with previous studies by Pandita *et al.*, (1989), Shivade *et al.*, (2011), Ahmed and Kamaluddin (2013), Mohamadali *et al.*, (2004), Prasanth *et al.*, (2015), and Dawane *et al.*, (2020). Therefore, direct selection for these traits would be beneficial in improving seed yield per plant.

Conversely, certain traits exhibited a low and negative direct effect towards seed yield per plant. These include plant height under late and very late conditions; days to first flowering under all three conditions; days to 50% flowering in timely and late conditions; days to pod initiation in timely and late conditions; pod length in timely and very late conditions; days to maturity under all three conditions; pod width in late conditions; tuber length in all three conditions; dry pod weight and tuber weight in very late conditions; tuber diameter in late and very late conditions; and tuber weight in late conditions.

4.18. D² Analysis

Genetic divergence analysis plays a crucial role in identifying genetically diverse genotypes for use in plant breeding programs. The D² analysis is particularly useful for quantifying the degree of divergence between biological populations at the genotypic level. It also helps estimate the relative contributions of different components to the overall divergence, both at the inter- and intra-cluster levels.

Winged bean, being widely distributed across various geographical regions, possesses a large spectrum of genetic diversity. Therefore, measuring

genetic divergence through biometrical analysis is essential for the proper selection of parents in crop improvement programs.

4.18.1. Contribution of Characters Towards Divergence

Among the sixteen characters (as shown in Table 4.12), tuber weight made the highest contribution to the total genetic diversity, followed by tuber width, days to first flowering, tuber length, dry pod weight, plant height, pod yield per plant, seed yield per plant, days to maturity, number of pods per plant, pod length, 100-seed weight, and days to 50% flowering. The least contribution was observed in pod width.

These findings suggest that to select genetically diverse genotypes, the primary focus should be on evaluating tuber weight and tuber width.

4.18.2. Genetic Diversity in Different Groups

Based on the D^2 values, 40 genotypes were grouped into five clusters (Table 4.9). Cluster I contained the highest number of genotypes (33), followed by cluster II (3) and cluster V (2). The classification of these 40 genotypes into five clusters indicates a considerable amount of genetic diversity. Therefore, careful selection of parents from these genotypes, based on optimal genetic divergence, is essential. Similar findings for different winged bean genotypes have been reported by Pali and Mehta, (2015), Nizar and Mulani (2015), Chandrawati *et al.*, (2017), Kumari *et al.*, (2018), Chauhan *et al.*, (2018), Samantara *et al.*, (2020), and Yulianah *et al.*, (2020).

The intra-cluster D^2 values revealed that cluster V, which includes only two genotypes, exhibited the maximum genetic diversity within the cluster, followed by cluster I. Clusters III and IV, each represented by a single genotype, had zero intra-cluster distance.

The inter-cluster D^2 values indicated the greatest diversity showed between clusters II and V, followed by clusters III and V, while the minimum diversity was observed between clusters I and III. Based on these results, the

genotypes from clusters I and III were found to be the most divergent. Therefore, these genotypes, particularly those with high mean performance for most important quantitative traits, could be used in breeding programs.

The clustering pattern can serve as a guide for selecting parental combinations in breeding programs aimed at generating the highest possible variability in yield components. Parents with a high yield potential and wide range of genetic diversity are likely to produce superior segregants in a short period (Maurya and Singh, 1977).

Mian and Bhal (1989) also reported that parents separated by high D^2 values tend to exhibit high heterosis. These findings suggest that the following cluster combinations should be prioritized for making crosses: Cluster I $\times$ Cluster II and Cluster I $\times$ Cluster V.

4.18.3. Analysis of Cluster Means

Based on the cluster means (Table 4.11), the genotypes of cluster II were found to be superior in traits such as days to first flowering, days to 50% flowering, days to pod initiation, days to maturity, pod yield per plant, number of pods per plant, number of seeds per pod, 100-seed weight (g), and seed yield per plant (g). Similarly, the genotypes of cluster IV were found to be superior in traits such as pod length (cm), pod width (cm), dry pod weight (g), tuber length (cm), tuber weight (g), and tuber width (cm). These findings are consistent with those reported by Yulianah *et al.*, (2020).

4.19. Stability Analysis

Meteorological differences across environments and considerable variation in preceding genotypes lead to differences in sowing times across regions. Therefore, it is important to identify genotypes that perform well under different sowing times to ensure optimal yield levels when sown at varying times. In this investigation, the performance of different genotypes across six

environments was studied, and the results are discussed in this chapter under the appropriate sub-headings.

4.19.1. Genotype × Environment Interaction Studies

The productivity of a population is a function of its adaptability. Significant advancements in crop production can be achieved by breeding varieties with stable yields and yield components. Plant breeding involves managing genetic variability, and breeders seek greater variability in crop plants to develop strains that provide maximum yield across different environments and exhibit consistent performance.

While there is no direct measurement of genetic variability, it can be inferred from the phenotype, which shows a function of genotype, environment, and their interaction. The phenotype often changes when a genotype is grown in varying environments. It has been shown that interactions are common regardless of the material's nature. The interaction between genetic and non-genetic factors affecting phenotypic expression is called the genotype × environment ($G \times E$) interaction. This interaction is widely present and significantly contributes to the non-realization of expected gains from selection (Comstock and Moll, 1963). Stable genotypes are especially important in countries like India, where crops are grown under varied environmental conditions and are subject to risk.

The $G \times E$ interaction plays a pivotal role in the evaluation and execution of breeding programs. Allard and Bradshaw (1964) critically reviewed this phenomenon and discussed its implications in applied plant breeding. Thus, the $G \times E$ interaction is important for the expression of quantitative traits, which are controlled by polygenic systems and are heavily influenced by environmental fluctuations.

Identifying stable genotypes is challenging due to the presence of $G \times E$ interactions. Although plant breeders have observed genetic differences in

adaptability, they have not been able to fully exploit these differences in breeding stable genotypes. This is largely due to the difficulty in defining and measuring phenotypic stability. Several attempts have been made to characterize genotype behavior in response to varying environments. The statistical approach by Finlay and Wilkinson (1963) has been particularly useful in measuring phenotypic stability. They used linear regression slope (b_i) as a measure of stability. This regression analysis was later improved by Eberhart and Russell (1966), who introduced an additional parameter, deviation from regression (S^2_{di}), to account for unpredictable irregularities in genotype responses to varying environments.

Various methods have been proposed over time to statistically analyze $G \times E$ interactions. Growing a set of genotypes under multiple environments and conducting a combined analysis helps assess $G \times E$ interactions and compare different genotypes. However, this approach does not provide a dynamic interpretation of the stability of individual genotypes. The most widely used method in this respect is the regression technique, where the $G \times E$ interaction component of variability is partitioned into its linear and non-linear portions to assess genotype stability across a range of environments. This is known as joint regression analysis. Several researchers have contributed to the development of this approach, including Finlay and Wilkinson, (1963), Eberhart and Russell, (1966), and Freeman and Perkins, (1971).

Information on the relative stability of genotypes for different yield components is essential. The results of the stability parameters estimated for various characters are discussed below to identify the most suitable conditions for each genotype. In the present study, forty winged bean genotypes were studied through $G \times E$ interaction and stability analysis. The stability of the genotypes was assessed *via*, the Eberhart and Russell, (1966) model.

4.19.2. Pooled Analysis of Variance Based on the Eberhart and Russell Model (1966)

The pooled analysis of variance for phenotypic stability, as per Eberhart and Russell (1966), revealed that mean differences due to genotypes were statistically significant for majority of the traits, including days to first flowering, days to 50% flowering, days to maturity, number of pods per plant, number of seeds per pod, seed index (100-seed weight), seed yield per plant, pod yield per plant, tuber diameter, tuber weight, tuber length, pod width, pod length, dry pod weight, days to pod initiation and plant height when tested against $G \times E$ interaction (Table 4.13). This observation suggests that there is substantial variability in the genotypes evaluated.

The highly significant $G \times E$ interaction observed for traits such as days to first flowering, days to 50% flowering, seed index (100-seed weight), seed yield per plant, tuber weight, tuber length, pod length, and plant height indicates that genotypes showed varied responses to different environments.

On the other hand, the pooled analysis of variance for phenotypic stability according to Eberhart and Russell (1966) also indicated that mean differences due to genotypes were statistically significant for the traits plant height, days to first flowering, days to 50% flowering, days to maturity, days to pod initiation, number of seeds per pod, number of pods per plant, pod yield per plant, pod width (cm), seed yield per plant (g), dry pod weight (g), tuber length (cm), tuber diameter (cm), and tuber weight (g), except for 100-seed weight (g) and pod length (cm) when tested against $G \times E$ interaction (Table 4.13). This observation further supports the existence of substantial variability in the genotypes evaluated.

The significance of pooled deviation (non-linear) effects on the traits such as days to first flowering, days to 50% flowering, days to maturity, number of pods per plant, number of seeds per pod, seed index (100-seed weight), seed

yield per plant, pod yield per plant, tuber diameter, tuber weight, tuber length, pod width, pod length, dry pod weight, days to pod initiation, and plant height is also depicted in (Table 4.13).

4.19.3. Stability parameters and Genotype x Environment interactions:

The interaction of genotype and environment always contributes to the stability of genotypes. The use of regression coefficient to explain the response of genotypes is a approach for estimating the stability (Eberhart and Russell 1966). The optimum level of performance of a genotype in a specific environment is adoption and stable performance of a genotype over an array of the environments is adoptability this could be explained through its GxE interaction based on “individual buffering” (developmental homeostasis) and “population buffering” (genetic homeostasis). “Individual buffering” belongs to genetically homogenous population such as inbred lines or pure lines and “population buffering” refers to the buffering which is raised from the interaction of different co-existing genotype (heterogeneous population). It was quite evident from the results that character-wise dissimilar pattern of genotype - environmental interaction observed among studied genotypes.

The linear regression slope (b_i) was employed by Finlay and Wilkinson (1963) to assess stability. Further, during evaluating the stability for phenotypic characters of genotypes using G x E interactions, Eberhart and Russell (1966) highlight the significance of both the regression coefficient (b_i) and the deviation from regression (S^2d_i). The most stable genotype according to Bains and Gupta, (1972) would have a high average performance, a coefficient of regression that does not fluctuate significantly from zero, and a deviation mean square that is near to zero. They also suggested that genotypes regardless of regression coefficient or S^2d_i be labelled as poor adapted if their mean yields were lower than the pooled mean. Consequently, genotypes with average performance higher than the mean population and with non-significant S^2d_i which emphasize;

- a. b_i approaching unity insignificantly are with general stability or average stability.
- b. b_i is significantly greater than 1 when evaluated in favourable conditions (below average stability).
- c. b_i is less than unity, indicating that it is suited to a unfavourable environment (above average stability).

According to Eberhart and Russell, (1966), genotype with significant S^2d_i have been specified as unstable.

The estimation of environmental indices (Table 4.22) which shows that the environment 2nd E2 was favourable and got 4 characters viz., plant height, days to first flowering, days to 50% flowering and number of pods per plant also environment 5 was also favourable for 4 characters *i.e.* pod width, dry pod weight, plant yield plant. Environment E4 was suitable for tuber length and seed yield per plant followed by environment, E1 with days to maturity. while environment 5 did not met any specific favourable characteristics but comprised of many positive characters with moderate indices.

The environment indices for all the traits under study (table 4.22) revealed that none of the trait had positive indices in all the six environments. Mean performance of environments revealed that E₁ and E₄ recorded the least and unfavourable environment for most of the traits. When we compare the result of different environments under studied, it clearly showed that E₂ was the most favourable environments for maximum number of traits followed by E₃ and E₆ as the favourable sowing date for the different characters. Hence, E₂ and E₃ were considered as the recommended date of sowing in the present study.

The stability parameters assessed for diverse traits (Table 4.16 to 4.21) facilitated to recognize genotypes with overall and adopt specifically. Studying the stability of yield components is essential in this regard.

Among the different environmental experiment, plant height (Table 4.23) of genotype viz., NUWB-3 revealed higher mean values, regression coefficient

more than unity and deviations from regressions revealed that these genotypes were adapted to favourable environments. The genotypes 4 genotypes viz., Loal wokha-2, NUWB-1, VRWB-50 and VRWB-23 revealed higher mean values, regression coefficient lower than unity and deviations from regressions revealed that these genotypes were adapted to unfavourable environments. Whereas, no genotype showed average stability across the environment. The linear and non-linear components of environment was highly significant for plant height indicating the unpredictable nature of environment. These results are in concomitant with earlier reports of Popalghat *et al.*, (1998), Sirohi *et al.*, (2001), Vijay Prakash (2005), Chaudhary *et al.*, (2012), Shafi *et al.*, (2012), Chaturvedi *et al.*, (2013), Shivani and Sreelaxmi (2015), Sharma and Johnson (2017), Mulema *et al.*, (2019), Harish *et al.*, (2020), Prasanthi *et al.*, (2021), Tare *et al.*, (2023) and Kumawat (2023).

For days to first flowering (Table 4.23) 3 genotypes viz., VRWB-100, VRWB-112 and VRWB-116 revealed lower mean values, regression coefficient more than unity and deviations from regressions revealed that these genotypes were adapted to favourable environments. Whereas no genotypes revealed lower mean values, regression coefficient lower than unity and deviations from regressions revealed that these genotypes were adapted to unfavourable environments. Whereas, no genotype was found for unity regression which shows average stability across the environment. The linear and non-linear components of environment was highly significant for days to first flowering indicating the unpredictable nature of environment. These results are in concomitant with the earlier reports of Bhojane (2015) and Shanna and Johnson (2017).

Days to pod initiation (Table 4.24) revealed 14 genotypes viz., VRWB-17, VRWB-20, VRWB23, VRWB24, VRWB-26, VRWB-35, VRWB-93, VRWB-77, VRWB-112, VRWB-115, Local dimapur-2, Local akuk, VRWB-50 and VRWB-54 revealed lower mean values, regression coefficient more

than unity and deviations from regressions revealed that these genotypes were adapted to favourable environments. Whereas no genotypes revealed lower mean values, regression coefficient lower than unity and deviations from regressions revealed that these genotypes were adapted to unfavourable environments. Whereas, no genotype was found for unity regression which shows average stability across the environment. The linear and non-linear components of environment was highly significant for days to first flowering indicating the unpredictable nature of environment. These results are in concomitant with the earlier reports of Bhojane, (2015) and Shanna and Johnson, (2017).

On the basis of stability model pod length (Table 4.24) exhibit two genotype NUWB-4 and Local wokha-1 revealed higher mean values, regression more than unity and showed their performance for favourable environment which were to be count stable while five genotypes viz VRWB-20, Local pangti-1, Local dimapur-1, Local pangti-2 and Local dimapur-2 revealed higher mean values, regression less than unity were adaptable in unfavourable environment. Whereas, one genotypes NUWB-1 was found for bi equals to unity regression which shows average stability across the environments. The linear and non-linear components of environment was highly significant for pod length indicating the unpredictable nature of environment.

On the basis of stability model pod width (Table 4.25) exhibit no genotype revealed higher mean values, regression more than unity and showed their performance for favourable environment which were to be count stable while five genotypes Local dimapur-1, VRWB-45, Local dimapur-3, VRWB-75 and VRWB-116 revealed higher mean values, regression less than unity were adaptable in unfavourable environment. meantime, one genotypes VRWB-116 was found for bi equals to unity regression which shows average stability across the environments. The linear and non-linear components of

environment was highly significant for pod width indicating the unpredictable nature of environment.

Dry pod weight (in Table 4.25) no genotype was revealed to be lower mean values, regression coefficient more than unity and deviations from regressions which were adapted to favourable environments. Also, zero genotypes revealed to be lower than the mean values, regression coefficient lower than the unity and deviations from regressions which were adapted to unfavourable environments. Thus, no genotype showed stable performance over the environments as seen from non-significant deviation and b_i values is unity. The linear and non-linear components of environment was highly significant for dry pod weight indicating the unpredictable nature of environment.

For the trait days to 50 % flowering (Table 4.23) single genotypes VRWB-23 revealed lower mean values, regression coefficient more than unity and deviations from regressions revealed that these genotypes were adapted to favourable environments. whereas 13 genotype Local Medziphema, VRWB-85, Local baghty, VRWB-17 VRWB-20, VRWB-24, VRWB-50, VRWB-54, VRWB85, VRWB93, VRWB-100, VRWB-112 and Local dimapur-2 revealed lower mean values, regression coefficient lower than unity and deviations from regressions revealed that these genotypes were adapted to unfavourable environments. Whereas, no genotype was found for unity regression which shows average stability across the environment. The linear and non-linear components of environment was highly significant for days to 50% flowering indicating the unpredictable nature of environment. These results are in concomitant with the earlier findings of Bhojane (2015) and Shanna and Johnson (2017).

For the days to maturity (Table 4.24) seven genotypes Local Medziphema, Local dimapur-3, VRWB-88, VRWB-100, VRWB-112, VRWB-115 and NUWB-2 revealed lower mean values, regression coefficient

more than unity and deviations from regressions revealed that these genotypes were adapted to favourable environments. 5 genotypes viz Local dimapur-1, Local wokha-1, VRWB-75, VRWB-77 and VRWB-116 on revealed lower mean values, regression coefficient lower than unity and deviations from regressions revealed that these genotypes were adapted to unfavourable environments. The study revealed that no genotype showed stable performance over the environments as seen from non-significant deviation and b_i values is unity. The linear and non-linear components of environment was highly significant for seed index indicating the unpredictable nature of environment. These results are concomitant with the earlier findings of Baisakh and Nayak, (1991), Singh *et al.*, (1993), Singh and Kumar (1993), Popalghat *et al.*, (1998), Sirohiet *et al.*, (2001), Vijay Prakash, (2005), Karpe *et al.*, (2013), Shivani and Sreelaxmi, (2015), Bhojane, (2015), Sharma and Johnson, (2017), Mulema *et al.*, (2019), Varma *et al.*, (2019), Prasanthi *et al.*, (2021), Tare *et al.*, (2023) and Kumawat, (2023).

On the basis of stability model tuber diameter (Table 4.26) exhibit six genotype VRWB-77, Local baghty, VRWB-93, VRWB112, Local suchonoma and Local Dimapur-1 revealed higher mean values, regression more than unity and showed their performance for favourable environment which were to be count stable while eight genotypes viz Local wokha-2, VRWB-26 VRWB-27, VRWB-36, Local Pangti-1, Local Pangti-2, VRWB-59, Local Mongsenyimti, NUWB-2, Local Dimapur-2, and VRWB-50 revealed higher mean values, regression less than unity were adaptable in unfavourable environment. Whereas, two genotypes Local Medziphema and VRWB-85 was found for b_i equals to unity regression which shows average stability across the environments. The linear and non-linear components of environment was highly significant for tuber diameter indicating the unpredictable nature of environment. These results are in support with the earlier findings of Shivani

and Sreelaxmi, (2015), Bhojane, (2015), Sharma and Johnson, (2017), Varma *et al.*, (2019), Prasanthi *et al.*, (2021), Tare *et al.*, (2023) and Kumawat, (2023).

Among the other traits tuber length (Table 4.25) on the basis of stability model, two genotypes *viz.*, VRWB-23 1 revealed higher mean values, regression more than unity and showed their adaptable performance for favourable environment and two genotypes *viz.* Local Akuk and local Dimapur-3 revealed higher mean values, regression less than unity were adaptable in unfavourable environment. Whereas, one genotype Local Wokha-1 was found for unity regression which shows average stability across the environments also none of the genotypes found to be stable in both conditions with bi value equals to unity. The linear and non-linear components of environment was highly significant for tuber diameter indicating the unpredictable nature of environment.

On the basis of stability model it has been showed that pod yield per plant (Table 4.26) which is count to be an important trait for the quality enhancement for winged bean exhibits four genotype VRWB-26, VRWB-100, VRWB-115 and Local Medziphema which revealed higher mean values, regression more than unity and showed their performance for favourable environment which were to be count stable while two genotypes *viz.* VRWB-27 and Local Dimapur-3 revealed higher mean values, regression less than unity were adaptable in unfavourable environment. Whereas, no genotypes was found for bi equals to unity regression which shows average stability across the environments. The linear and non-linear components of environment was highly significant for pod yield per plant indicating the unpredictable nature of environment.

In case of the traits number of seed per pod (Table 4.27), On the basis of stability model five genotype *viz.*, Local Mongsenyimti, VRWB-20, VRWB-36, Local pangti-2 and Local dimapur-1 revealed higher mean values, regression more than unity and showed their performance for favourable environment which were to be count stable four genotypes *viz.*, VRWB-17, VRWB-27,

NUWB-1 and VRWB-32 showed higher mean values, regression less than unity was adaptable in unfavourable environment. Whereas, one genotypes Local Mongsenyimti was found for bi equals to unity regression which shows average stability across the environments. The linear and non-linear components of environment was highly significant for number of seed per pod indicating the unpredictable nature of environment. Similar findings were found for Bharatiya *et al.*, (2017) Monndo *et al.*, (2019), Harish *et al.*, (2020), Tiwari *et al.*, (2020), Mulema *et al.*, (2019), Raiger *et al.*, (2019), Yuliana *et al.*, (2020).

Among the traits number of pods per plant (Table 4.27), On the basis of stability model four genotype viz., VRWB-45, VRWB-50, VRWB-59, VRWB-100 disclose higher mean values, regression more than unity and showed their performance for favourable environment which were to be count stable one genotypes viz Local peren revealed higher mean values, regression less than unity were adaptable in unfavourable environment. Whereas, one genotypes VRWB-59 was found for bi equals to unity regression which shows average stability across the environments. The linear and non-linear components of environment was highly significant for number of pods per plant implay the unpredictable nature of environment.

For tuber weight (Table 4.26) four genotypes viz Local Suchonoma, VRWB-23, VRWB-26, Local Pangti-2, and VRWB-115 revealed lower mean values, regression coefficient more than unity and deviations from regressions revealed that these genotypes were adapted to favourable environments. While no revealed lower mean values, regression coefficient lower than unity and deviations from regressions indicating that these genotypes were adapted to unfavourable environments. Whereas, no genotype was found for unity regression which shows average stability across the environment. The linear showed non-significant for the tuber weight and non-linear components of environment was highly significant for tuber weight indicating the unpredictable nature of environment.

For 100 seed weight (Table 4.28), On the basis of stability model four genotype Local Wokha-2, NUWB-4, Local Dimapur-1 and Local Dimapur-3 revealed higher mean values, regression more than unity and showed their performance for favourable environment which were to be count stable three genotypes viz Local Suchonoma, VRWB-59 and VRWB-104 revealed higher mean values, regression less than unity was adaptable in unfavourable environment. Whereas, no genotypes were found for b_i equals to unity regression which shows average stability across the environments. The linear and non-linear components of environment was highly significant for 100 seed weight indicating the unpredictable nature of environment.

The higher seed yield per plant (Table 4.28) is the prime goal of this experiment and this is relevantly the most important trait. The study revealed that six genotype NUWB-4, Local Medziphema, VRWB-17, VRWB-23, VRWB-36 and VRWB-88 showed stable performance over the environments as seen from non-significant deviation and b_i values being nearer to unity. higher mean values, regression coefficient more than unity and deviations from regressions it's been revealed that these genotypes were adapted to favourable environments only. The genotypes Whereas five genotypes viz Local Suchonoma, VRWB-27, VRWB-59, VRWB-100, VRWB-105 and VRWB-11 revealed revealed higher mean seed yield, regression coefficient lower than unity and deviations from regressions revealed that these genotypes were adapted to unfavourable environments only. The linear and non-linear components of environment was highly significant for grain yield indicating the unpredictable nature of environment. Whereas, four genotype VRWB-36, Local Pangti-1, Local Dimapur-1 and NUWB-4 was found for unity ($b_i=1$) was found for b_i equals to unity regression which shows average stability across the environments. These results are in conformity with the earlier reports of Mehra and Rarnanujan (1979), Sharma and Maloo, (1989) Singh *et al.*, (1993), Popalghat *et al.*, (1998), Sirohi *et al.*, (2001), Chaudhary and Haque (2010),

Desai *et al.*, (2016), Tolga *et al.*, (2018), Varma *et al.*, (2019), Harish *et al.*, (2020), Prasanthi *et al.*, (2021), Harosh Al-Qaisi and Hindi Al-Bayati, (2023), Tare *et al.*, (2023) and Kumawat *et al.*, (2023).

4.19.4. Additive main effect and multiplicative interaction (AMMI) and Genotype main effects plus the genotype-by-environment interaction (GGE)

GEI may be measured using parametric techniques like regression and ANOVA. However, utilising these methods to predict genotype stability is not reliable since they do not account for genotypes' overall reaction to surroundings. This is because parametric approaches treat a genotype's reaction to environment as univariate approach, which is actually a multivariate issue (Lin *et al.*, 1986). In an attempt to get around this, the concept of genotype grouping based on response structure has surfaced. This kind of classification's primary benefit is that it is not dependent on any particular collection of examined data, meaning that the relative correlations between the genotypes remain constant. ANOVA and PCA are combined into a single, integrated method called additive main effect and multiplicative interaction (AMMI), which was proposed by Zobel *et al.*, (1988), Crossa *et al.*, (1990), Gauch and Zobel (1996), and can be used to analyse multilocation trials. The genotype (G) main effects plus the genotype-by-environment interaction (GEI) effects are visually represented by the "GGE Biplot," a biplot approach recently developed by Yan *et al.*, (2000). Although environmental variation was frequently found to be substantially larger (>80%) than G+ GEI variation (<20%), it was nonetheless noted that G and GE are the two primary sources of variation that are significant for evaluating cultivars.

Here is the revised version of your writing with improved grammar, clarity, and flow:

4.19.5. Phenotypic Stability Analysis Based on the AMMI Model

The significant effects of location, genotype, and their interactions on

seed yield per plant (g) were revealed through the integration of analysis of variance and principal component analysis (PCA) (Fig. 4.21 to 4.29). Our research demonstrates the importance of genotype-environment interactions in achieving ideal yields under various conditions. The first three principal components (PCs) explained the variability, exceeding the minimal reliability criterion. Similar findings were reported by Neisse *et al.*, (2018) and Harish *et al.*, (2020). The explanatory power of our study, which considers three PCs, shows a substantial level of reliability, as evidenced by Smith, P.L. (1978), Roostaei *et al.*, (2022), and Matongera *et al.*, (2023).

In case of seed yield per plant, the AMMI 1 biplot experiment categorized genotypes into two groups based on their adaptation patterns (Fig. 4.21). The first group comprised 19 genotypes with higher seed yield per plant: VRWB-20 (G7), VRWB-17 (G6), VRWB-26 (G11), VRWB-88 (G31), Local Wokha-2 (G1), VRWB-36 (G16), VRWB-23 (G8), VRWB-59 (G26), VRWB-100 (G34), VRWB-85 (G30), VRWB-116 (G39), VRWB-27 (G12), Local Suchonoma (G2), Local Medziphema (G5), VRWB-112 (G37), VRWB-45 (G19), Local Dimapur-1 (G18), Local Pangti-1 (G17), and NUWB-1 (G3), all with positive PC1 scores, which were desirable based on their interaction with the environment. The second group consisted of 21 genotypes, including VRWB-24 (G9), VRWB-93 (G33), NUWB-2 (G40), Local Dimapur-2 (G21), VRWB-54 (G24), Local Mongsenyimti (G36), NUWB-3 (G10), Local Peren (G4), VRWB-35 (G15), Local Wokha-1 (G25), VRWB-75 (G28), Local Dimapur-3 (G27), VRWB-115 (G38), VRWB-104 (G35), Local Baghty (G32), VRWB-50 (G23), Local Akuk (G22), NUWB-1 (G13), VRWB-77 (G29), Local Pangti-2 (G20), and G14, which had negative PC1 scores and lower seed yield per plant, thus not being retained in the breeding scheme. Similarly, environments showed variation in both main effects and interaction effects (Fig. 4.22).

Duarte and Vencovsky (1999), Zobel *et al.*, (2014), M'Benga (1989), Gauch, H.C. (1988a), Gauch, H.C. (1988b), Gauch, H.C. (1997), Gauch, H.C. (2013), Jorben *et al.*, (2022), and Danakumara *et al.*, (2023) also reported that AMMI 1 evaluates stability along the Y-axis (PC1). However, AMMI 2 analysis identified stable environments and genotypes based on their proximity to the origin with low scores for both interaction axes (PC1 and PC2). Environments were classified as either favorable or unfavorable based on their effect on seed yield per plant for a genotype. The environments located close to the X-axis were considered stable, while environments with higher seed yield on the right side of the Y-axis were classified as unstable, forming the second group of environments.

Genotypes such as Local Peren (G4), Local Suchonoma (G2), VRWB-54 (G24), VRWB-20 (G7), VRWB-26 (G11), and VRWB-27 (G12), along with environments E1, E2, and E6, were identified as the most responsive or interactive, as they were located far from the origin (0, 0) (Purchase, 1997). On the other hand, genotypes like VRWB-50 (G23), Local Pangti-2 (G20), Local Dimapur-1 (G18), and Local Dimapur-2 (G21), which were located closer to the origin, were considered non-sensitive to environmental interaction (Fig. 4.41). Similar results have been observed by Sarker *et al.*, (2004), Anandan *et al.*, (2009), Azam *et al.*, (2020), Rao *et al.*, (2023), and Danakumara *et al.*, (2023).

4.19.6. Winning Genotype and Mega-Environment:

The "which-won-where" analysis of the multi-environment trial (MET) provided crucial insights into the potential existence of different mega-environments. The polygon of lines, formed by connecting straight lines between vertex genotypes, shows the genotypes located at the vertices, while the remaining genotypes fall within the polygon. For seed yield per plant, the vertex genotypes were VRWB-54 (G24), Local Pangti-2 (G20), VRWB-32 (G14), NUWB-1 (G13), Local Mongsenyimti (G36), Local Wokha-2 (G1), and VRWB-20 (G7) (Fig. 4.25).

Since these genotypes are the farthest from the origin, they are either the most fortunate or the least fortunate under certain environments. According to the GGE biplot analysis of forty-winged bean genotypes evaluated across six environments (Fig. 4.23, 4.24 and 4.25), the first two principal components (PC1 and PC2) explained the majority of the variation. Genotypes located closer to the origin are sensitive to environmental changes, while those farther from the origin have stronger interactions with their environments and more stable relationships. Genotypes and environments located near the origin are considered more stable, as they have zero scores on both interaction axes (PC1 and PC2).

The analysis also aimed to identify super-environments, providing critical information about the "which-won-where" scenario. This scenario involves combining at least one environment with similar characteristics into a larger, unified mega-environment. In the case of seed yield per plant, only one super-environment was identified. This mega-environment included all six environments (E1, E2, E3, E4, E5, and E6), with VRWB-20 (G7) identified as the winning genotype.

This finding suggests that evaluating germplasm in smaller mega-environments could provide consistent, reliable yield data. The GGE biplot analysis offers valuable insights that can guide breeders in making informed decisions, particularly in understanding the relationship between genotypes and environments. The results highlight the potential bias that may arise when $G \times E$ interactions are not considered and stress the importance of using $G \times E$ biplot analysis.

The GGE analysis allows for a comprehensive evaluation of genotypes and environments, considering both their average performance and stability across conditions. It provides critical information for breeders, enabling them to identify the most suitable genotypes for specific environments. Super-

environments, as defined in this analysis, refer to environments or conditions that consistently exhibit the best diversity. This concept has been supported by several studies (Kang MS, 1993; Gomez, 2004; Kang MS, 2002; Kilic H, 2014; Kanouni *et al.*, 2015; Kendal *et al.*, 2016; Achenef and Alimou, 2020; Abou-Khater *et al.*, 2022; Greveniotis *et al.*, 2022; Danakumara *et al.*, 2023; Balbo *et al.*, 2024; Paramanik *et al.*, 2024; Pornsuria *et al.*, 2024). These findings enable breeders to make more targeted recommendations for promising genotypes suited to specific environmental conditions. The "which-won-where" analysis determines the optimal genotypes for each mega-environment.

4.19.7. The Relationship Among Test Environments:

The GGE biplot provides an overview of the relationships between test environments through the position of their vectors. Additionally, the length of an environmental vector offers an estimate of how effectively the environment can distinguish between genotypes (Fig. 4.26). The results from this study demonstrated that the first principal component (PC1) and the second principal component (PC2) independently explained the variation in the data (Fig. 4.26). Together, PC1 and PC2 accounted for the overall variation in the sample, allowing us to extract correlations between different environments using the biplot.

An extended environmental vector indicates a stronger ability to differentiate genotypes. Environments with the longest vectors from the origin were the most effective in separating the genotypes, while those with shorter vectors still managed to segregate the genotypes reasonably well. For seed yield per plant, environments E1, E5, and E6 had the longest vectors from the origin, while environments E2, E3, and E4 had the shortest vectors (Fig. 4.25).

The vector perspective of the GGE biplot provides a concise summary of how the environments relate to one another. Two environments are considered strongly related if the angle between their vectors is less than 90°, negatively

correlated if the angle is greater than 90°, and independent if the angle is exactly 90°. In this study, since the angle between the vectors for most environments was less than 90°, the environmental conditions were strongly correlated (Figures 4.3 to 4.47).

The Average Environment Coordinate (AEC), represented by a small circle, intersects both the average environment and the biplot's origin. Test environments with smaller AEC values are more representative of other test conditions. This finding is aligned with the results of Samonte *et al.*, (2005), Padi FK (2007), Rad *et al.*, (2013), Sayar *et al.*, (2013), and Dhanakumara *et al.*, (2023).

4.19.8. Discriminativeness vs. Representativeness:

The "Discriminativeness vs. Representativeness" pattern in the genotype plus genotype-by-environment (GGE) biplot is a crucial tool for determining the best test environments for selecting superior genotypes. The pattern first discriminates between genotypes and then reflects the entire set of tested environments accurately (representativeness).

The Average Environment Coordinate (AEC), represented by a small circle, intersects both the average environment and the biplot origin. A test environment that shows alignment with the AEC is more representative of other testing conditions. In this study, the genotype assessment across various environments revealed greater genotypic variation for the evaluated winged bean genotypes. For seed yield per plant, environments E2 and E4 represented the best environments, followed by E3 (Fig. 4.27). These findings corresponds with those of Samonte *et al.*, (2005), Padi FK, (2007), Rad *et al.*, (2013), Jifar *et al.*, (2019), Sayar *et al.*, (2013), and Danakumara *et al.*, (2023). Variations in these environments could be attributed to annual fluctuations in climate, soil fertility, and other natural factors. These results suggest that there is a highly suitable testing environment for high-yielding varieties.

4.19.9. Assessment of Genotypes Based on the Ideal Genotype

An ideal genotype is one that consistently performs well and yields the highest across all test environments. In GGE biplot analysis, concentric circles are drawn centered on the ideal genotype to illustrate the distance between each genotype and this perfect genotype. The major concentric circle typically represents the ideal genotype, and genotypes positioned closer to this circle are considered more desirable.

In this study, genotype G6 (VRWB-17) was positioned closer to the ideal genotype in the biplot, indicating that it is a promising candidate for evaluation. Genotypes near the ideal genotype are considered more desirable because they exhibit strong performance across environments. On the other hand, genotypes farther from the ideal genotype are less preferred, even if they are more suited to specific environments. Genotypes near the biplot origin exhibited lower susceptibility to environmental changes, making them more stable and desirable compared to other genotypes.

4.19.10. Mean Performance vs. Stability of the Genotypes

The "mean performance vs. stability" analysis in the genotype plus genotype-by-environment (GGE) biplot is a valuable method for assessing genotype stability across different environments. In **Fig. 4.29**, the abscissa of the Average Environment Coordinate (AEC) indicates that seed yield per plant is higher across various environments. This figure presents the GGE biplot analysis of forty genotypes evaluated under four environments.

Using the AEC method, genotypes with the highest seed yield per plant included VRWB-20 (G7), VRWB-17 (G6), VRWB-26 (G11), VRWB-88 (G31), and Local Wokha-2 (G1) (Fig. 4.29). These genotypes showed the most positive PC1 values and performed the best, according to practical experience.

When making decisions, both stability and high yield should be considered in relation to the overall environment. In terms of PC2, the genotypes

closest to the center of the biplot showed greater stability and higher-than-expected seed yields. These genotypes included VRWB-59 (G26), Local Suchonoma (G2), and Local Pangti-1 (G17) (Fig. 4.29). The genotype closest to the center for PC1 was identified as the most effective in terms of performance.

Therefore, the genotypes closest to the center for both PC1 and PC2 were consistently high-yielding and stable. Plant breeders aim to identify germplasm that ensures both high yield and stability across different environments. These results are consistent with previous studies by Smith, P.L. (1978), Gauch, H.C. (1988a), Gauch, H.C. (1988b), Gauch, H.C. (1997), Gauch, H.C. (2013), Roostaei *et al.*, (2022), Jorben *et al.*, (2022), and Danakumara *et al.*, (2023).

This finding suggests that the ideal genotype is not far from the existing genotypes in the study. For seed yield per plant, genotype G6 (Fig. 4.28) was identified as the ideal genotype. These findings are consistent with those of Tai GCC (1979), Thillainathan and Fernandez (2001), Yan W (2001), Akinyose *et al.*, (2023), Azam *et al.*, (2020), Segherloo *et al.*, (2010), Yan W (2010), and Danakumara *et al.*, (2023).

4.20. Protein Content in Green Pods and Seeds

The protein content observed in the green pods (Table 4.31), ranging from 28.17% to 20.15%, is consistent with previous studies that have highlighted the winged bean as an excellent source of protein compared to other legumes. The highest protein levels were recorded in genotypes VRWB-23, VRWB-75, and Local Pangti-2, demonstrating their potential as high-protein sources. Notably, genotypes that outperformed the check variety, Local Medziphema (23.47%), indicate that substantial improvements in protein content could be achieved by selecting specific high-protein genotypes. The average protein content of 24.29% in the green pods further supports the winged bean's status as a nutrient-dense food source.

Protein content in the seeds was considerably higher than in the green pods, ranging from 30.55% to 49.07%. This disparity underscores the significance of seeds as a concentrated protein source. The highest protein percentages were found in VRWB-23, Local Pangti-1, and Local Pangti-2, which notably exceed the protein content of common legumes like soybean, which typically contains 36-40% protein. These high-protein genotypes could be prioritized in breeding programs to develop protein-rich seed varieties, offering a valuable alternative protein source for both food and feed applications.

Similar findings were reported by Hildebrand *et al.*, (1981), Sathe (1982), Gross (1983), Thanh Van *et al.*, (1985), Philip and Ramachandran, (1986), Eltayeb *et al.*, (1997), Mohamadali, (2001), Bhattacharya *et al.*, (2005), Kaur and Kawatra, (2002), Amoo *et al.*, (2006), Li-Wen *et al.*, (2010), Awoyale *et al.*, (2018), Moyib *et al.*, (2019), Adegboyega *et al.*, (2019), Chakraborty *et al.*, (2019), Yusuf and Adamu (2019), Pratap *et al.*, (2020), Ushakumari *et al.*, (2021), Singh *et al.*, (2019), Jain *et al.*, (2021), Wani *et al.*, (2020), Nguyen *et al.*, (2021), Chumchuere and Whitaker (1989), and Giri and Janmejaya (2006).

4.21. Oil Content in Seeds

The oil content observed in winged bean seeds (Table 4.31), ranging from 14.80% to 6.13%, suggests that some genotypes may be valuable sources of oil. The highest oil content was found in genotypes such as VRWB-116 and VRWB-85, which exceed the typical oil content of other legumes like lentils and chickpeas. This positions the winged bean as a potential crop for edible oil production. However, the lower oil content in certain genotypes, such as Local Pangti-1 (6.13%), indicates genetic variability that can be utilized for specific breeding objectives, depending on whether a high-protein or high-oil trait is desired.

Similar outcomes have been reported by Mohamadali, (2001), Philip and Ramachandran, (1986), Bhattacharya *et al.*, (2005), Amoo *et al.*, (2006),

Bressani *et al.*, (1982), Rao and Shanthi, (1992), Balogun *et al.*, (1981), Hildebrand *et al.*, (1981), Oshodi *et al.*, (1993), Chandel and Dhillon (1990), Oguntona and Fetuga (1983), Mohanty *et al.*, (1988), Rachie and Silvestre (1980), Nwokolo, (1987), Li-Wen *et al.*, (2010), Adegboyega *et al.*, (2019), Nguyen *et al.*, (2020), Khan *et al.*, (2021), Okpara *et al.*, (2018), Ajayi *et al.*, (2017), Udomkun *et al.*, (2019), Lai *et al.*, (2021), and Mahajan *et al.*, (2018).

The three genotypes that exceeded the check variety, Local Suchonoma (13.60%), in oil content show potential for developing winged bean varieties that offer a balance of both protein and oil, making them suitable for multifunctional use. This dual benefit of high protein and oil content could increase the economic value of the crop, making it an attractive option for both nutritional and industrial applications.

4.22. Chlorophyll Content in Winged Bean

The evaluation of chlorophyll content across various winged bean genotypes highlights the genetic variability within the species and underscores the potential for selecting genotypes with improved chlorophyll characteristics. Chlorophyll, a critical pigment in photosynthesis, plays an essential role in plant growth and productivity, as well as contributing to the nutritional and functional value of winged beans in human diets. The significant variation in total chlorophyll, chlorophyll-a, and chlorophyll-b content observed among the genotypes suggests differing photosynthetic efficiencies, which may influence crop yield and resilience to environmental stress.

4.23. Total Chlorophyll Content:

The total chlorophyll content (Table 4.32) showed that genotypes such as VRWB-27, VRWB-24, VRWB-100, VRWB-104, and VRWB-116 exhibited significantly higher chlorophyll levels than the average and surpassed the check variety, Local Medziphema. These genotypes may possess superior photosynthetic activity, potentially contributing to greater biomass production and higher yield. Their elevated chlorophyll concentration also indicates

potential for nutrition-focused applications, as higher chlorophyll levels are often associated with increased antioxidant properties. Similar findings have been reported by Owuor and Ojijo (1991), Silva *et al.*, (1995), Sinha (2014), Zhao *et al.*, (2018), Samyor *et al.*, (2019), Hossain *et al.*, (2020), Nguyen *et al.*, (2021), Chatterjee *et al.*, (2019), Rao and Deshpande (2019), Naveen *et al.*, (2020), and Wang *et al.*, (2021).

4.24. Chlorophyll-a Content:

Chlorophyll-a, which plays a primary role in photosynthesis by converting light energy into chemical energy, showed notable variation among the genotypes (Table 4.31), with values ranging from 0.917A in Local Medziphema to 0.441A in VRWB-20. However, none of the genotypes surpassed Local Medziphema for chlorophyll-a content, indicating that it remains a benchmark for this trait in winged bean. High chlorophyll-a levels in genotypes such as VRWB-27, VRWB-23, and VRWB-24 suggest that these could be promising candidates for breeding programs aimed at improving photosynthetic efficiency. Given that chlorophyll-a is directly involved in light absorption and energy conversion, genotypes with elevated levels could be more efficient in energy use, potentially improving crop yield in light-limited environments. Similar findings have been reported by Owuor and Ojijo (1991), Silva *et al.*, (1995), Sinha (2014), Zhao *et al.*, (2018), Samyor *et al.*, (2019), Hossain *et al.*, (2020), Nguyen *et al.*, (2021), Chatterjee *et al.*, (2019a), Rao and Deshpande (2019), Naveen *et al.*, (2020), and Wang *et al.*, (2021).

4.25. Chlorophyll-b Content:

Chlorophyll-b assists chlorophyll-a by expanding the light spectrum absorbed, which is particularly beneficial under low-light conditions. Genotypes such as VRWB-27, VRWB-24, VRWB-100, and VRWB-104 demonstrated high chlorophyll-b content (Table 4.31), indicating their potential for greater resilience in diverse lighting environments. However, none of the genotypes surpassed Local Medziphema for chlorophyll-b content, highlighting the check

variety as a valuable resource for balanced chlorophyll-a and chlorophyll-b levels. The variability in chlorophyll-b content also presents opportunities to enhance stress tolerance and adaptability in winged bean through selective breeding. Similar results have been reported by Owuor and Ojijo, (1991), Silva *et al.*, (1995), Sinha (2014), Zhao *et al.*, (2018), Samyor *et al.*, (2019), Hossain *et al.*, (2020), Nguyen *et al.*, (2021), Chatterjee *et al.*, (2019b), Rao and Deshpande (2019), Naveen *et al.*, (2020), and Wang *et al.*, (2021).

CHAPTER VI

SUMMARY AND CONCLUSION

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The proposed investigation entitled “**Genotype x environment interaction analysis and variation studies in winged bean [*Psophocarpus tetragonolobus* (L.) DC.]**” was carried with a view to study genetic variability, genetic diversity, correlation coefficient, path coefficient analysis and stability analysis in winged bean for yield, yield contributing characters and quality characters. Twenty-three genotypes were procured from IIVR, Varanasi and seventeen genotypes were procured from SAS, Medziphema, Nagaland. for the study. The forty genotypes were evaluated using Randomized Block Design (RBD) with three replication at three different date of sowing viz., SAS, Medziphema, Nagaland during 2022-23 and 2023-24 in six different environments i.e., 16th march in 2022-23 (E1), 26th March in 2022-23 (E2), 5th April in 2022-2023(E3), 16th march in 2023-24 (E4), 26th march in 2023-24(E5 and 5th April in 2023-2024 (E6). The data's were recorded on sixteen characters viz., plant height (cm), days to 50% flowering, days to maturity, days to pod initiation, days to first flowering, Pod length (cm), Pod width (cm), Dry pod weight (g), Tuber weight (g), Tuber diameter(cm), Tuber length(cm), Pod yield per plant (g), Number of pod per plant, number of seed per pod, 100 seeds weight (g) and seed yield per plant(g) and yield attributing traits along with important quality characters in each environment were subjected to statistical analysis.

From the research trials following salient findings came into light:

1. Analysis of variance indicated significant genetic variability for the traits under study in both timely, late and very late environments. In timely conditions, the yield and direct yield-related traits namely, pod yield per plant (1048.63) across the environment followed by seed yield per plant (990.31), days to pod initiation (328.54) and number of

2. Pods per plant (51.39) in late condition followed by days to maturity (380.51), and tuber length (48.77) in timely sown condition and days to 50 % flowering (311.65) and tuber weight (354.13) in very late condition. The lowest value was recorded for pod width (0.04). Under timely sown condition, showed widerange of genotypic variability. The overall population mean of these traits were higher in winged bean genotypes grown under timely conditions in comparison to those grown under late and very late condition.
3. In the present investigation, on the basis of *per se* performance viz., most promising genotypes in respect of seed yield per plant (g) were VRWB-17, VRWB-20, Local Wokha-2, VRWB-26 and VRWB-36 as they recorded higher seed yield per plant.
4. The trait-wise difference between phenotypic and genotypic coefficient of variation (GCV) was very low. However, the genotypic coefficient of variation was higher (>20)for some of the traits studied such as tuber weight, tuber diameter, seed yield per plant number of pods per plant, pod yield per plant and tuber length.
5. A higher heritability (bs) i.e. >70 was observed for. Higher heritability was observed for the traits like plant height, days to first flowering, days to 50% flowering, days to pod initiation, days to maturity, pod width, dry pod weight, tuber length, tuber weight, tuber diameter, number of pods per plant, pod yield per plant and seed yield per plant exhibited higher heritability under timely, late and very late condition.
6. High heritability, along with high genetic advance as a percentage of the mean, was observed for several traits under different planting conditions: Timely condition: Plant height, days to first flowering, days to 50% flowering, days to pod initiation, days to maturity, dry pod weight, pod yield per plant, number of pods per plant, tuber weight, tuber length, and seed yield per plant. Late condition: Plant height, days

to first flowering, days to 50% flowering, days to pod initiation, pod length, dry pod weight, pod yield per plant, number of pods per plant, tuber length, tuber weight, and seed yield per plant. Very late condition: Tuber weight, tuber diameter, and seed yield per plant.

7. One of the most critical traits, seed yield per plant, exhibited a highly significant positive correlation at both genotypic and phenotypic levels with traits like pod yield per plant, 100-seed weight, number of pods per plant, and number of seeds per pod. However, days to 50% flowering, plant height, days to pod initiation, days to maturity, and pod length showed a significant negative correlation with pod yield per plant at both genotypic and phenotypic levels.
8. Path coefficient analysis revealed that, for both phenotypic and genotypic path analysis, the highest positive direct effect on seed yield per plant was recorded for pod yield per plant, number of seeds per pod, number of pods per plant, 100-seed weight, and plant height. This indicates a true and direct relationship between these traits and seed yield per plant.
9. Negative direct effect was observed on seed yield per plant-by days to 50% flowering followed by days to maturity, pod length, days to first flowering and tuber length. Negative direct effects of above characters might be due to their negative indirect effects *via* another trait on them.
10. The D^2 analysis indicated wider genetic diversity among forty genotypes of winged bean which were grouped in five different clusters by Tocher's method. The results indicated that a maximum number of diverse genotypes (33 genotypes) were appeared in cluster I followed by cluster II (3 genotypes), whereas cluster V (2 genotypes), cluster III and IV were mono-genotypic, consisted of single genotype. These genotypes are likely to have extreme form of expression for particular character.
11. The Intra-cluster distance (D) ranged from 0.00 to 9.89. At intra-

cluster level, cluster V had the highest intra cluster distance with 2 genotypes followed by cluster I and cluster -2 which involved 33 and 3 genotypes, respectively. The intra-cluster distance within cluster III and IV was zero (0) because these clusters were composed of only single genotype.

12. The maximum inter-cluster distance ($D=42.24$) was observed between cluster II and V followed by those between cluster III and V and cluster I and V. It was concluded that the genotypes from the cluster II and V were more divergent than any other cluster. Hence, the genotypes belonged to the distinct cluster (II and V) could be used in hybridization program for obtaining a wide spectrum of variability among the segregates in winged bean.
13. In the present study, tuber weight, followed by tuber width, Days to first flowering, tuber length, dry pod weight, plant height, pod yield per plant, seed yield per plant, days to maturity and number of pod per plant appeared to be the most important traits contributing maximum towards genetic divergence, while harvest index and days to maturity contributed very low towards total divergence.
14. Selection of genotypes for plant height (cm) had tall characters, long pod length, high dry-pod weight and higher number of seed per pod was desirable characters can be procured from cluster III while days to 50% flowering, days to pod initiation and days to maturity had very short flowering period and suitable for early maturing will be highly desirable from cluster II. Also, Selection of genotypes for higher seed yield per plant, pod yield per plant and numbers of pod per plant respectively from cluster II will be highly promising. Selection of genotypes for 100 seed weight and tuber diameter from cluster IV will be highly promising. Selection of genotypes for pod width (cm), tuber length(cm) and tuber weight from cluster V will be highly desirable.

Selection of genotypes for all the characters from cluster I was moderately highly promising

15. In G x E interaction study as per Eberhart and Russel model, the analysis of variance was highly significant except for plant height, dry pod weight and tuber width. However, the analysis of variance for traits in genotypes was all significant. In linear component of G x E interaction, all traits were highly significant except plant height and tuber weight. However, all the traits were highly significant in linear component of environment. Additionally, the pooled deviation (non-linear) all traits were significant.
16. The genotypes VRWB-36, Local Pangti-1, Local Dimapur-1 and NUWB-4 were highly stable across the environments because of high seed yield (g), near unit regression coefficient and non-significant deviation from regression. The genotypes NUWB-4, Local Medziphema, VRWB-17, VRWB-23, VRWB-36 and VRWB-88 were stable under favourable environment. The genotypes VRWB-27, VRWB-59, VRWB-100, VRWB-105 and VRWB-116 were stable under unfavourable environment.
17. For G x E interaction analysis based on the AMMI model, the mean squares due to genotypes, environment as well as G x E interaction was highly significant for all the traits and G x E was further partitioned into three principal component (PC I, PC II and PC III) and these components were also highly significant for all the traits.
18. From AMMI1 and AMMI2 biplot genotype VRWB-20 was the best performer across the environment for seed yield (152.40 g). Among the environments, environment E3, E4 and E5 was the most favourable for seed yield per plant.
19. The “which won where” biplot identified environments E1 and E3 (Timely) forming first mega environment; E2 and E4 (Late) forming

second mega environment. For seed yield per plant, there is only one super condition. In this mega-environment all environments E1, E2, E3, E4, E5 and E6 included and the winning genotype is VRWB-20 (G7).

20. The “mean vs. stability” biplot identified that the genotypes which were closest to the point in terms of PC2 were VRWB-59 (G26), Local Suchonoma (G2) and Local Pangti-1 (G17) were steadily improving with higher Seed yield per plant than anticipated. The most factor genotype is identified as VRWB-20 (G7). Thus, NUWB-1 (G3) and VRWB-45 (G19), showed increasing stability that corresponded to seed yield per plant.

21. The protein content of green pods ranged from 30.55 % to 49.07% and the protein percent of seeds ranged from 28.17 % to 20.15% with average mean of 24.29%, Simultaneously, highest protein content was observed in VRWB-23 and lowest in Local Dimapur-3 for protein content in seeds, for protein content in pods highest was observed for VRWB-23 and lowest was observed for Local suchonoma all condition.

22. Oil content was observed highest for VRWB-116 and lowest was observed for Local Pangti-1 in all condition.

CONCLUSION

The following points can be concluded from the present research titled “**Genotype X Environment interaction analysis and variation studies in winged bean [*Psophocarpus tetragonolobus* (L.) DC.]**”:

- ✚ A wide range of genetic variability was present among the genotypes for yield and yield-related traits constituting of tuber weight, pod yield per plant, days to first flowering, days to 50% flowering, days to maturity, days to pod to maturity and seed yield per plant.
- ✚ A high GCV was recorded for tuber length, tuber weight, seed yield per plant, number of pods per plant and pod yield per plant under both conditions. Also, high heritability was observed in tuber weight, seed yield per plant, tuber yield per plant, days to pod initiation and dry pod weight.
- ✚ High yielding genotypes viz., VRWB-17, VRWB-20, Local Wokha-2, VRWB-26 and VRWB-36 could be further evaluated by selection techniques.
- ✚ The D² analysis indicated that divergent clusters III and IV revealed high genetic diversity available in given studies, which indicated that these clusters would be used for further breeding programmes.
- ✚ In Eberhart and Russel based G x E interaction, analysis identified VRWB-36, Local Pangti-1, Local Dimapur-1 and NUWB-4 were found most stable under all three conditions.
- ✚ In AMMI and GGE biplot analysis, VRWB-20 was identified as stable and high yielding.
- ✚ Genotype VRWB-23 exhibited the highest protein content among all evaluated genotypes in both the green pod and seed portions.

✚ Genotype VRWB-116 exhibited the highest oil content among all evaluated genotypes.

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